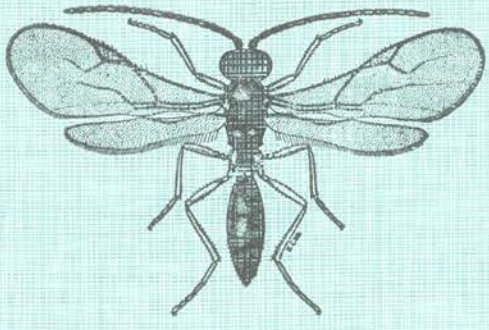
Special publication No. 10 July, 1971

BIOLOGICAL CONTROL OF CITRUS, VEGETABLES AND TOBACCO APHIDS

CHIA-CHU TAO AND SHUI-CHEN CHIU



Published by

THE TAIWAN AGRICULTURAL RESEARCH INSTITUTE

TAIPEI, TAIWAN, CHINA

Final Report of the PL-480 Research Project on Biological Control of Citrus, Vegetables and Tobacco Aphids

(1965-1970)

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Title of the Project: Biological Control of Citrus, Vegetables and Tobacco Aphids

Grant Number: PL-480 Grant No. FG-TA-112 (A6-Ent-4)

Period: April 16, 1965 to April 15, 1970.

Signed:

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Taiwan Agricultural Research Institute

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BIOLOGICAL CONTROL OF CITRUS VEGETABLES AND TOBACCO APHIDS

CHIA-CHU TAO AND SHUI-CHEN CHIU

Abstract. Aphids in subtropical countries apparently take anholocycle year round. The loss caused by aphid transmitted virus is much greater than direct infestation by aphids. This report presents 8 major aphids of citrus, vegetables and tobacco. Their parasites and predators were also surveyed.

The parasites such as *Aphidius gifuensis*, *Ephedrus persicae*, *Aphelinus* sp. of green peach aphid and *Trioxys communis* of cotton aphid have already been introduced to the United States. The most active predators in checking aphid population are *Lemnia swinhoei* in citrus groves, *Coccinella septempunctata bruckii* and *Menochilus sexmaculatus* in cruciferous vegetable fields. Hoverflies are uncertain due to different species occurring in different seasons, while predacious activity of aphis-lions is inferior to coccinellids and hoverflies.

Citrus black aphid, *Toxoptera citricida* is a major citrus aphid which is toxic to most species of coccinellids and all species of aphis-lions except *Lemnia swinhoei*, *L. biplagiata*, *Propylaea japonica*, *Coelophora chinensis* and *Scymnus* spp. However, many species of hoverflies are unaffected. Turnip aphid, *Lipaphis erysimi* is toxic to the larvae of the above 2 species of *Lemnia* but it is not harmful to other aphid-feeding coccinellids. Consequently, using indigenous predators or parasites for biological control of citrus and vegetables aphids would not be successful in Taiwan.

The systemic insecticide, Azodrin WSC was shown to be a good chemical for bark treatment of citrus. The painting began at the start of the growth flush and repeated 7-10 days later. It is not only used to control young foliage insects such as aphids, leaf miner, whiteflies, jumping plant lice, mealy bugs, soft scales, armored scales, stink bugs and red mite, but also to reduce citrus dogs infestation. Bark treatment instead of spraying could also preserve the natural enemies of citrus insects and avoid the side effect of the citrus mite problem.

Introduction

The study of biological control of citrus, vegetables and tobacco aphids was approved and granted by the United States Department of Agriculture under Public Law 480, as a 5-year project (A6-Ent-4) begun on April 16, 1966 and terminated on April 15, 1970. The total grant was NT$ 1,106,200.

The survey of natural enemies was not limited to aphids on citrus, vegetables and tobacco but also covered other crops and plants for complete biological and ecological observations of aphid hosts and their enemies.

The main surveying area was located in Taipei, the northern part of Taiwan, but we also extended the collecting area to southern part of Taiwan and up to the mountain area when it was required at certain seasons.

15 research staff were hired under this project, during different periods within 5 years. Those who assisted for only a few months are not listed.

The natural enemies were obtained and classified as 2 species of Aphelinidae, 18 species of Aphidiidae (Hymenoptera); 1 species of Hemerobiidae, 3 species of Chrysopidae (Neuroptera); 1 species of Anthocoridae (Hemiptera); 1 species of Anystidae, Acarina (Arachnida); 16 species of Coccinellidae (Coleoptera); 14 species of Syrphidae and 1 species of Chamaemyiidae (Diptera). They were found as parasitic in or feeding on the 7 species of citrus aphids, each 3 species of vegetable aphids on Cruciferae, Leguminosae, Umbelliferae, Compositae, Liliaceae, Gramineae and 1 species of aphid attacking Nymphaeaceae vegetables and tobacco.

Because of the work involved on the manuscript and drawings, this final report is published one year later than anticipated. The authors would like present their deepest apology to the governers and entomologists of both countries.

PART I: General Consideration on Citrus, Vegetables and Tobacco Aphids in Taiwan

7 species of aphids attacking citrus; 3 species each on Cruciferae, Leguminosae, Umbelliferae, Compositae, Liliaceae, Gramineae, Solanaceae; 2 species on Malvaceae and 1 species each on Nymphaeaceae and tobacco are listed below:

I. List of citrus, vegetables and tobacco aphids

Citrus aphids

Toxoptera citricida (Kirkaldy); *Toxoptera aurantii* (Boyer de Fonscolombe); *Toxoptera odinae* (van der Goot); *Aphis spiraecola* Patch; *Aphis gossypii* Glover; *Myzus persicae* (Sulzer); *Sinomegoura citricola* (van der Goot).

Cruciferae vegetable aphids

Lipaphis erysimi (Kaltenbach); *Brevicoryne brassicae* (Linne); *Myzus persicae* (Sulzer).

Leguminosae vegetable aphids

Aphis craccivora Koch; *Aphis glycines* Matsumura; *Acyrthosiphon pisum* (Harris).

Umbelliferae vegetable aphids

Aphis spiraecola Patch; *Cavariella salicicola* (Matsumura); *Semiaphis heraclei* (Takahashi).

Compositae vegetable aphids

Brachycaudus helichrysi (Kaltenbach); *Dactynotus formosanus* (Takahashi); *Uromelan gobonis* (Matsumura).

Liliaceae vegetable aphids

Indomegoura indica (van der Goot); *Myzus hemerocallis* (Takahashi); *Neotoxoptera formosana* (Takahashi).

Gramineae vegetable aphids

Longiunguis sacchari (Zehntner); *Rhopalosiphum maidis* (Fitch); *Rhopalosiphum padi* (Linnaeus).

Nymphaeaceae vegetable aphid

Rhopalosiphum nymphaeae (Linnaeus).

Tobacco aphid

Myzus persicae (Sulzer).

Actually there are only 24 species of aphids attacking the above 3 groups of crops. They may be identified in the field by the following keys.

II. Field key to the species of citrus, vegetables and tobacco aphids

Citrus aphids

1. Body black, brown or pink 2
   Body green, yellowish green or dark green, rarely pink..... 5
2. Color of adult and nymph different, adult shining black and nymph brown... 3
   Color of adult and nymph brown 4
3. Body comparatively large; 3rd antennal joint of alate form black; stigma of wing brown, median vein branched twice .....*Toxoptera citricida*
   Body comparatively small; 3rd antennal joint of alate form pale; stigma of wing black, median vein branched only once.....*Toxoptera aurantii*
4. Body comparatively large with cornicles slightly swollen and a little longer than cauda; cauda elongate, little constricted near middle.....
   ..... *Sinomegoura citricola*
   Body comparatively small with cornicles cylindrical and little shorter than cauda; cauda thick, slightly narrowed near middle .....*Toxoptera odinae*
5. Body comparatively large, pale green to pink; frons well developed with mesal side converging and median inwarded; cornicles cylindrical, sometimes swollen; cauda elongate, more or less tapering at apex; dorsum of alate form with a large black rectangular patch .....*Myzus persicae*
   Body comparatively small, yellowish green to dark green; frons not so well developed; cornicles cylindrical, never swollen; cauda elongate, rounded at apex; dorsum of alate form without a large black rectangular patch... 6
6. Body yellowish green; usually living in curled leaf .....*Aphis spiraecola*
   Body dark green (on other hosts are pale, pale yellow or yellowish green); usually living on opened leaf .....*Aphis gossypii*

Cruciferae vegetable aphids

1. Body naked without any waxy secretion; size comparatively large; frons well developed with mesal side converging and median inwarded; alate form with a black rectangular abdominal patch ....*Myzus persicae*

Body covered with waxy secretion, size comparatively small; frons not well developed, mesal side and median shallow, wave shaped; dorsum of alate form with some dotted or transverse black lines 2

2. Body green, densely covered with white waxy powder; wing venations clear; abdomen with a few transverse black lines .....*Brevicoryne brassicae*

Body yellowish green, faintly covered with white waxy powder; wing venations infuscated along veins; abdomen with some transversely black dotted spots ..... *Lipaphis erysimi*

LEGUMINOSAE VEGETABLE APHIDS

1. Nymph body with waxy secretion, infesting string bean, horse bean, cow bean, peanut and vetch .....*Aphis craccivora*

Nymph body clean, without waxy secretion, infesting pea, soybean, etc..... 2

2. Body larger, light green, antennal tubercles protruded, infesting pea, vetch and horse bean .....*Acyrthosiphon pisum*

Body smaller, yellowish green, antennal tubercles not well protruded, infesting soybean.....*Aphis glycines*

UMBELLIFERAE VEGETABLE APHIDS

1. Nymph body covered with waxy secretion, in curled leaves.....*Semiaphis heraclei*

Nymph body clean, without waxy secretion, on opened leaves 2

2. Body yellowish white, with supra caudal projection, cornicles swollen..... ..... *Cavariella salicicola*

Body yellowish green, without supra caudal projection, cornicles cylindrical ..... *Aphis spiraecola*

COMPOSITAE VEGETABLE APHIDS

1. Body smaller, greenish; cauda short, pentagonal .....*Brachycaudus helichrysi*

Body red-brown; cauda elongate, much longer than wide..... 2

2. Body red, median part black; cauda white, infesting lettuce .... *Dactynotus formosanus*

Body entirely black, infesting great burdock .....*Uromelan gobonis*

LILIACEAE VEGETABLE APHIDS

1. Infesting leak, onion and garlic; body shiny blackish brown, wings heavily clouded along veins.....*Neotoxoptera formosana*

Infesting hemerocallis; body greenish brown 2

2. Body naked, greenish; infesting sheath .....*Myzus hemerocallis*

Body covered with waxy secretion, brown; infesting leaf .....*Indomegoura indica*

GRAMINEAE VEGETABLE APHIDS

1. Body yellowish white; wings infuscated along veins .....

.. .. *Longiunguis sacchari*
Body grayish green or brownish green; wing venation clear 2
2. Body comparatively elongate, grayish green; legs entirely black.....
..... *Rhopalosiphum maidis*
Body comparatively broad, brownish green, legs part of tibiae pale.....
..... *Rhopalosiphum padi*

MALVACEAE VEGETABLE APHIDS

1. Body comparatively large, pale green to pink; frons well developed with mesal side converging and median inwarded; cornicles cylindrical, sometimes swollen; cauda elongate, more or less tapering at apex; dorsum of alate form with a large black rectangular patch .....*Myzus persicae*
Body comparatively small, yellowish green to dark green; frons not so well developed; cornicles cylindrical, never swollen; cauda elongate, rounded at apex; dorsum of alate form without a large black rectangular patch .....*Aphis gossypii*

SOLANACEAE VEGETABLE APHIDS

1. Body comparatively large, pale green to pink; frons well developed; cauda elongate, more or less tapering at apex 2
Body comparatively small, yellowish green to dark green; frons not so well developed; cauda elongate, more or less rounded at apex .....*Aphis gossypii*
2. Frontal tubercles converging; cornicles sometimes swollen; dorsum of alate form with a large black rectangular patch .....*Myzus persicae*
Frontal tubercles diverging; cornicles never swollen; dorsum of alate form without a large black rectangular patch .....*Aulacorthum solani*

III. Host plants of citrus, vegetables and tobacco aphids

Acyrthosiphon pisum (Harris) (green pea aphid)
Hosts: Leguminosae: *Astragalus sinicus* Linn., *Pisum sativum* Linn., *Vicia faba* Linn., *Vigna sinensis* (Linn.) Endl.; Myricaceae: *Myrica rubra* Sieb.

Aphis craccivora Koch (black bean aphid)
Hosts: Leguminosae: *Arachis hypogaea* Linn., *Astragalus sinicus* Linn., *Crotalaria saltiana* Andr., *Desmodium heterocarpum* (Linn.) DC, *Dolichos lablab* Linn., *Phaseolus lunatus* Linn., *Phaseolus mungo* Linn., *Pisum* sp., *Pithecolobium dulce* (Roxb.) Benth., *Trifolium* sp., *Vicia faba* Linn., *Vigna sequipedalis* Pierters, *Vigna sinensis* (Linn.) Endl.; Malvaceae: *Gossypium* sp.; Thymelaeaceae: *Wikstroemia indica* C. A. Mey.

Aphis glycines Mats. (soybean aphid)
Host: Leguminosae: *Glycine max* (Linn.) Merrill.

Aphis gossypii Glover (cotton aphid)
Hosts: Acanthaceae: *Justicia procumbens* Linn.; Aceraceae: *Acer* sp.; Amarantaceae: *Amaranthus mangostanus* Linn.; Araceae: *Caladium* sp., *Colocasia esculenta*

Schott.; Araliaceae: *Acanthopanax trifoliatum* (Linn.) Merrill; Bombacaceae: *Bombax ceiba* Linn.; Casuarianaceae: *Casuarina equisetifolia* Linn.; Compositae: *Bidens bipinnata* Linn., *Bidens pilosa* Linn., *Blumea balsamifera* (Linn.) DC, *Chrysanthemum sinensis* Makino, *Chrysanthemum* sp., *Cirsium segtum* (Linn.), *Erigeron linifolius* Willd., *Gnaphalium* sp., *Lactuca debilis* Benth. et Hook. f.; Cruciferae: *Capsella bursapastoris* Moench; Cucurbitaceae: *Citrullus vulgaris* Schrad, *Cucumis sativus* Linn., *Cucurbita maxima* Duchesne, *Cucurbita moschata* Dich, *Luffa cylindrica* Roem.; Euphorbiaceae: *Breynia* sp., *Euphorbia hirta* Linn., *Euphorbia* sp., *Phyllanthus reticulatus* Poir.; Hamamelidaceae: *Liquidambar formosana* Hance.; Leguminosae: *Pachyrrhizus erosus* Urban, *Medicago sativa* Linn.; Labiatae: *Leonurus sibiricus* Linn., *Perilla ocymoides* Linn., *Salvia coccinea* Linn.; Lythraceae: *Lawsonia inermis* Linn.; Malvaceae: *Abelmoschus moschatus* Medic., *Gossypium herbaceum* Linn., *Gossypium* sp., *Hibiscus mutabilis* Linn., *Hibiscus rosasinensis* Linn., *Hibiscus sabdariffa* var. *altissima* Linn., *Hibiscus syriacus* Linn., *Hibiscus* sp.; Meliaceae: *Melia azedarach* Linn.; Myrtaceae: *Eucalyptus* sp., *Eugenia jambos* Linn., *Psidium guajava* Linn.; Nyctaginaceae: *Bougainvillea spectabilis* Willd.; Pedaliaceae: *Sesamum indicum* Linn.; Polygonaceae: *Antigonon leptopus* Hood. et Arn.; Portulacaceae: *Portulaca oleracea* Linn.; Punicaceae: *Punica granatum* Linn.; Rosaceae: *Eriobotrya japonica* Lindley, *Eriobotrya* sp., *Malus* sp., *Pyrus pyriofolia* Nakai.; Rubiaceae: *Gardenia jasminoides* Ellis, *Ixora chinensis* Lam., *Ourouparia formosana* Hayata, *Rubia cordifolia* Linn.; Rutaceae: *Citrus* spp.; Salicaceae: *Salix babylonia* Linn., *Salix* sp., *Salix glandulosa* Seem. var. *warburgii* (Seem) Koidzumi.; Scrophulariaceae: *Paulownia* sp., *Paulownia tomentosa* (Thunb.) Steud.; Solanaceae: *Capsicum annum* Linne, *Lycopersicum esculentum* Mill., *Solanum melongena* Linn., *Solanum torvum* Sw., *Solanum tuberosum* Linn.; Verbenaceae: *Callicarpa formosana* Rolfe, *Clerodendron trichotomum* Thumb., *Clerodendron* sp., *Tectona grandis* L. F., *Vitex negundo* Linn.,

Aphis spiraecola Patch (spirae aphis)

Hosts: Ericaceae: *Vaccinium donianum* Wight.; Rutaceae: *Citrus* spp.; Rosaceae: *Spiraea* sp.; Sapindaceae: *Dodonaea viscosa* (Linn.) Jacq.

Brachycaudus helichrysi (Kaltenbach)

Hosts: Compositae: *Ageratum conyzoides* Linn., *Bidens pilosa* Linn., *Eupatorium formosanum* Hayata; Rosaceae: *Prunus mume* Sieb. et Nacc., *P. persica* Batsch, *P salicina* Lindl.

Brevicoryne brassicae (Linn.) (cabbage aphis)

Hosts: Cruciferae: *Brassica cernua* Forbes et Hemsl., *Brassica oleracea* Linn. var. *botrytis* Linn., *Brassica oleracea* L. var. *capitata* DC., *Brassica pekinensis* Rupr., *Brassica rapa* Linn., *Brassica* spp., *Raphanus sativus* Linn.

Cavariella salicicola (Mats.) (willow aphid)

Hosts: Umbellaceae: *Apium petraselinum* Benth.; Rosaceae: *Rosa* sp.; Saliaceae: *Salix babylonia* Linn.

Dactynotus formosanus (Takahashi) (lettuce aphid)

Hosts: Compositae: *Chrysanthemum* sp., *Emilia sonchifolia* (Linn.) DC., *Ixeris laevigata* (Blumb.) Schr. var. *lanceolata* Makino, *Lactuca debilis* Benth. et Hook. f., *Lactuca formosana* Maxim., *Lactuca indica* Linn., *Lactuca sativa* Linn., *Sonchus oleraceus* Linn., *Senecio* sp.

Indomegoura indica (v. d. Goot) (daylily aphid)
Host: Liliaceae: *Hemerocallis falva* Linn.

Lipaphis erysimi (Kalt.) (turnip aphid)
Hosts: Cruciferae: *Brassica campestris* Linn., *Brassica cernua* Forbes et Hemsl., *Brassica chinensis* Makino, *Brassica Pe-tsai* Bailey, *Brassica oleracea* Linn. var. *capitata* DC., *Brassica oleracea* Linn., *Brassica rapa* Linn., *Capsella bursapastoris* Moench, *Raphanus sativus* Linn.; Compositae: *Chrysanthemum coronarium* Linn.; Papaveraceae: *Papaver somniferum* Linn.; Ranunculacae: *Ranunculus sceleratus* Linn.; Umbelliferae: *Apium graveolens* Linn.

Longiunguis sacchari (Zehn.) (sorghum aphid)
Hosts: Gramineae: *Andropogon* sp., *Miscanthus* sp., *Saccharum officinarum* Linn., *Zea mays* Linn.

Myzus hemerocallis Takahashi
Hosts: Liliaceae: *Hemerocallis aurantiaca* Baker, *H. fulva* Linn.

Myzus persicae (Sulzer) (green peach aphid)
Hosts: Aceraceae: *Acer* sp.; Amarantaceae: *Celosia aristata* Linn.; Apocynaceae; *Nerium indicum* Mill.; Araceae: *Colocasia esculenta* Schott.; Bombacaceae: *Bombax ceiba* Linn.; Caryophyllaceae: *Stellaria aquatica* Scop., *Stellaria media* Cyr.; Chenopodiaceae: *Chenopodium album* Linn.; Compositae: *Chrysanthemum* sp., *Helianthus annus* Linn., *Lactuca oldhami* Maxim., *Lactuca sativa* Linn., *Petasites tricholobus* Franch.; Convolvulaceae: *Ipomoea batatas* Lamk., *Ipomoea cairica* (Linn.) Sweet, *Ipomoea* sp., *Merremia gemella* (Burm. f.) Hallier f.; Crassulaceae: *Bryophyllum calycinum* Salisb.; Cruciferae: *Brassica campestris* Linn., *Brassica cernua* Forbes et Hemsl., *Brassica nipponica* Bailey, *Brassica oleracea* Linn. var. *botryits* Linn., *Brassica oleracea* Linn. var. *capitata* DC., *Capsella bursapastoris* Moench, *Raphanus sativus* Linn., *Raphanus* sp.; Cucurbitaceae: *Cucurbita moschata* Dich; Leguminosae: *Pisum sativum* Linn.; Malvaceae: *Abelmoschus moschatus* Medic.; Myrtaceae: *Eucalyptus robusta* Smith; *Psidium guajava* Linn.; Papaveraceae: *Papaver somniferum* Linn.; Pedaliaceae: *Sesamum indicum* Linn.; Rosaceae: *Prunus mume* Sieb. et Nucc., *Prunus persica* Batsch, *Prunus salicina* Lindley, *Prunus* spp., *Pyrus pyriofolia* Nakai, *Rosa* spp.; Rutaceae: *Citrus* spp.; Scrophulariaceae: *Antirrhinum majus* Linn.; Solanaceae: *Capsicum annum* Linn., *Lycium chinense* Mill., *Lycopersicum esculentum* Mill., *Nicotiana tabacum* Linn., *Solanum melogena* Linn., *Solanum tuberosum* Linn.; Ulmaceae: *Zelkova formosana* Hayata; Umbelliferae: *Apium graveolens* Linn., Verbenaceae: *Duranta repens* Linn.

Neotoxoptera formosana (Takahashi) (leek aphid)
Hosts: Liliaceae: *Allium fistulosum* Linn., *A. odorum* Linn., *A. scorodoprasum* Linn. var. *viviparum* Regel.

Rhopalosiphum maidis (Fitch) (corn aphid)
Hosts: Gramineae: *Echinochloa crusgalli* (Linn.) Beauv., *Hordeum sativum* Fessen, *Oryza sativa* Linn., *Triticum vulgare* Vill., *Zea mays* Linn.

Rhopalosiphum nymphaeae (L.) (lotus aphid)

Hosts: Alismataceae: *Sagittaria sagittifolia* Linn.; Araceae: *Pistia stratiotes* Linn. var. *asiatica* Engl.; Gentianaceae: *Limnanthemum indicum* (Linn.) Griseb.; Gramineae: *Oryza sativa* Linn.; Musaceae: *Musa* sp.; Nymphaeaceae: *Nelumbium nelmbo* Druce; Rosaceae: *Prunus mume* Sieb et Zucc., *Prunus persica* Batsch; Salicaceae: *Salix* sp. Salviniaceae: *Salvinia natans* (Linn.) Allione.

Rhopalosiphum padi (Linne) (barly aphid)

Hosts: Gramineae: *Triticum vulgare* Vill, *Zea mays* Linn., *Hordeum sativum* Fessen; Rosaceae: *Prunus mume* Sieb et Zucc., *Prunus persica* Batsch, *Prunus* spp.

Semiaphis heraclei (Takahashi) (celery aphid)

Hosts: Umbelliferae: *Apium graveolens* var. *dulce* DC., *Pteroselinum hortense* Hoffm, *Coriandrum sativum* Linn., *Cryptotaenia japonica* Hassak, *Daucus carota* var. *sativa* DC; *Oenanthe stolonifera* DC; Magnoliaceae: *Illicium anisatum* Linn., Caprifoliaceae: *Lonicera japonica* Thunb.

Sinomegoura citricola (van der Goot) (camphor aphid)

Hosts: Camelliaceae: *Camellia japonica* Linn.; Euphorbiaceae: *Bridelia ovata* Decne; Lauraceae: *Cinnamomum camphora* Sieb., *Lasianthus* sp., *Litsea* sp.; Moraceae: *Ficus harlandi* Benth.; Palmae: *Trachycarpus excelsus* Wendl.; Rutaceae: *Citrus* spp., *Murraya paniculata* Jack.

Toxoptera aurantii (Boyer de F.) (black citrus aphid)

Hosts: Anachardiaceae: *Mangifera indica* Linn.; Annonaceae: *Annona squamosa* Linn., *Annona* sp.; Apocynaceae: *Trachelospermum foetidum* (Mats. et Nak.); Aquifoliaceae: *Ilex rotunda* Thunb.; Araceae: *Caladium* sp.; Borraginaceae: *Ehretia dicksoni* Hance var. *japonica* Nak.; Camelliaceae: *Camellia japonica* Linn., *Camellia sinensis* (Linn.) O.K., *Thea* sp.; Caprifoliaceae: *Viburnum dilatatum* Thunb., *Viburnum odoratissimum* Ker.; Euphorbiaceae: *Macaranga tanarius* Muell.; Fagaceae: *Quercus* sp.; Flacourtiaceae: *Scolopia oldhamii* Hance; Leguminosae: *Cassia surattensis* Burm. f., Moraceae: *Artocarpus integra* (Thunb.) Merrill, *Ficus awkeotsang* Makino, *Ficus foveolata* Wall., *Ficus pumila* Linn., *Ficus retusa* Linn., *Morus alba* Linn., *Morus australis* Porr.; Myrsinaceae: *Measa tenera* Mez; Myrtaceae: *Eucalyptus rubusta* Smith; Pittosporaceae: *Pittosporum tobira* Ait.; Rhamnaceae: *Sageretia theezans* Brongn.; Rubiaceae: *Coffea arabica* Linn., *Gardenia augusta* Merr., *Gardenia jasminoides* Ellis, *Randia sinensis* Roem. et Schult, *Randia spinosa* (Thunb.) Poir.; Rutaceae: *Acronychia pedunculata* (Linn.) Miq., *Citrus* spp., *Murraya paniculata* (Linn.)Jack.; Salicaceae: *Salix babylonica* Linn., *Salix* sp., *Salix glandulosa* Seem. var. *warburgi* (Seem.) Koidz.; Sterculiaceae: *Theobroma cacao* Linn.; Styracaceae: *Styrax suberifolium* Hook et Arn.

Toxoptera citricida (Kirkaldy) (citrus aphid)

Hosts: Bombacaceae: *Bombax ceiba* Linn.; Camelliaceae: *Camellia japonica* Linn.; Euphorbiaceae: *Bridelia monoinca* (Lour.) Merr., *Bridelia ovata* Decne; Flacourtiaceae: *Xylosma congestum* (Lour.) Merr.; Lauraceae: *Cinnamomum camphora* Nees et Eberm; Moraceae: *Ficus retusa* Linn., Rosaceae: *Eriobotrya* sp.; Rubiaceae: *Lasianthus*

obliquinervis Merr. var. *nigrocarpus* (Masam.) Hatus.; Rutaceae: *Citrus grandis* Osb. f. *buntan* Hay., *Citrus* spp., *Poncirus trifoliata* Rafin.

Toxoptera odinae (van der Goot)

Hosts: Anacardiaceae: *Mangifera indica* Linn., *Rhus semialata* Murr. var. *roxburgnii* DC; Araliaceae: *Acanthopanax trifoliatum* (Linn.) Merrill, *Agalma lutchuense* Nakai; Burseraceae: *Canarium album* (Lour.) Raeuschel; Caprifoliaceae: *Viburnum dilatatum* Thunb., *Viburnum formosanum* Rehd., *Viburnum odoratissimum* Ker., *Viburnum* sp.; Euphorbiaceae: *Bischofia javanica* Bl., *Fluggea virosa* (Roxb.) Baill., *Sapium sebiferum* Roxb.; Guttiferae: *Garcinia multiflora* Champ.; Moraceae: *Ficus wightiana* Wall.; Myrtaceae: *Eucalyptus robusta* Smith; Pittosporaceae: *Pittosporum tobira* Ait.; Polygonaceae: *Antigonon leptopus* Hook; Rubiaceae: *Cinchona* sp., *Wendlandia erythroxylon* Cowan., *Wendlandia paniculata* DC.; Rutaceae *Citrus* spp., *Schefflera orboricola* Hay., *Zanthoxylum nitidum* (Roxb.) DC.

Uromelan gobonis (Mats.) (gobo aphid)

Hosts: Compositae: *Arctium lappa* Linn., *Blumea balsamifera* (Linn.) DC., *Chrysanthemum coronarium* var. *spatiosum* Bailey, *Chrysanthemum kawakamii* Hayata, *Gnaphalium multiceps* Wall., *Gaillardia aristata* Pursh, *Saussurea affinis* Spreng.

PART II: Aphid Parasites

This part of the report is the result of a general survey and bionomic study on the parasites of citrus, vegetables and tobacco aphids in Taiwan. It covers 17 species of aphids from 25 different kinds of vegetables; seven species of aphids from 11 varieties of citrus and one species of aphid from tobacco.

I. Citrus, vegetables and tobacco aphids and their parasites

Aphis gossypii Glover (cotton aphid)

A worldwide polyphagous species with 79 species of 32 families of host plants. It is recorded as attacking some of the important economic crops. It usually occurs in forest, parks, on weeds by roadsides and in vegetable fields. It was mixed with the colonies of other aphids such as *Aphis spiraecola* and *Greenidea psidii* when flushing. In March, April and October, the population of the aphid gradually increased towards its peak, and declined in August and December. The parasites of *Trioxys* (*B.*) *communis*, *Aphelinus mali*, *Lysiphlebia japonica*, *Aphelinus* sp. and *Lipolexis gracilis* were recorded, and *Trioxys* (*B.*) *communis* was found as the most effective one.

Aphis spiraecola Patch (spirae aphid)

A worldwide species, occurs in forests, parks, on roadsides, weeds and in orchards preferring to infest the young flush of its host plants, which includes a variety of economic citrus. The colonies were very frequently encountered on young citrus flush. The small colonies were regularly found in spring and

disappeared in summer, then the population was gradually recovered from October until December. During the abundant season, large colonies of spirae aphids usually attracted a few parasites, such as *Ephedrus (E.) robustus, Aphelinus mali, Lipolexis gracilis, Lipolexis scutellaris, Lysiphlebia japonica* with *Trioxys (B.) citri, E. (E.) robustus* and *Lipolexis gracilis* were found more often than the others, but none of them were specific to this aphid.

Brevicoryne brassicae (Linneaus) (cabbage aphid)

A worldwide species, the occurrence of which was rare in northern Taiwan in winter but quite often appeared in the mountain areas to attack green rape and cabbage. Only a few small colonies were found in Taipei area, it occasionally occurred and then disappeared quickly during winter and early spring. In the summer, vegetable cultivation of the mountain areas of Lishan and Shengkuang, has low temperature and dry weather which are both favorable to aphid reproduction. Consequently, it appeared as an essential pest on cabbage during the vegetable growing season in mountain areas from May to October. Two species of aphidiid parasites, *Diaeretiella rapae* and *Ephedrus (E.) persicae* were reared from those aphids.

Dactynotus formosanus (Takah.) (lettuce aphid)

This aphid is widely distributed and has been found all over northern Taiwan and South-East Asia. It occurred on the mountains and the lowlands of Taiwan on Compositae. From October to May, the aphids were rather abundant on lettuce. The parasites *Ephedrus (E.) plagiator* and *Praon dorsale* occurred very often on these aphid colonies.

Indomegoura indica (v. d. Goot) (daylily aphid)

This species occurs in the Far East and India. It was found occasionally in the lowland areas of Taiwan. We encountered daylily infested with aphids seriously in September of 1968 on the mountain of Lishan. These colonies had the parasite *Praon dorsale* but only a low population.

Lipaphis erysimi (Kalt.) (turnip aphid)

A worldwide species, mostly occurring in Taiwan on cruciferous vegetable such as radish, mustard, paitsai and cabbage. It is distributed over the coastal plains and low mountain areas. The aphids were very abundant from early January to mid-February and from November to December. The population may suddenly decrease from December to January because of disease. Meanwhile, the population of their parasites e. g. *Aphidius gifuensis, Ephedrus (E.) persicae* and *Diaeretiella rapae* were very low, and showed no preference to this aphid.

Longiunguis sacchari (Zehn.) (sorghum aphid)

It is widely distributed in South-East Asia, Africa and South America with a narrow host range, but was very common on some crops all year round. A great number of colonies were found on sugar cane, corn and sorghum particularly in

April, May, October and November. But the population of the parasites such as *Aphelinus* sp., *Lysiphlebia japonica*, *Ephedrus* (*E.*) *robustus* and *Lipolexis gracilis* were rather low. Sometimes *Lysiphlebia japonica* was found as a high percentage of the aphid colonies on *Miscanthus* or corn near mountain areas.

Myzus persicae (Sulzer) (green peach aphid)

A worldwide species occurring in gardens, orchards, on vegetables and tobacco in Taiwan. Its hosts cover 19 families. The occurrence of the aphid was mostly within a period of 6 months from November to April in lowland, while the cruciferous vegetables were the most favorable host-plants. Four species of parasites, *Aphidius gifuensis*, *Ephedrus* (*E.*) *persicae*, *Diaeretiella rapae* and *Lipolexis gracilis* were obtained from the aphid. *Aphidius gifuensis* has been found as the most common and specific parasite during the vegetable growing season.

From mid January to late February, a large number of green peach aphids were infected by a fungus disease. So the population of the aphid suddenly declined due to the low temperature, the fungus disease or the parasites. As soon as this period was over, the population of aphid recovered and maintained a normal population from then until May.

Rhopalosiphum maidis (Fitch) (corn leaf aphid)

A worldwide species, distributed in fields of corn, sorghum, rice and sugar cane and always causing serious damage during spring and autumn. However, very few parasites of this aphid were found. The parasitized mummies of *Ephedrus* (*E.*) *plagiator*, *Ephedrus* (*E.*) *robustus* and *Lipolexis gracilis* were occasionally found among large and dense aphid colonies.

Sinomegoura citricola (v. d. Goot) (camphor aphid)

This aphid occurs in South-East Asia, it mainly appears in forests, parks and sometimes attacks citrus which is cultivated near mountain sides. Its host plants consisted of 6 families. The aphid appears very commonly and abundantly during spring and autumn on *Cinnamomum camphora* and *Murraya exotica*. The population of parasites was very low. In the past 5 years survey, *Ephedrus* (*E.*) *plagiator* and *Trioxys* (*B.*) *struma* were encountered as the only parasites.

Toxoptera aurantii (Boyer) (black citrus aphid)

It is a worldwide species with 21 families of host plants in Taiwan. It was found on *Citrus* spp., *Mangifera indica* and *Coffee arabica*, often occurred in orchards, forests and gardens and co-existed with *Toxoptera citricida* (Kirkaldy) on Citrus. Its seasonal population gradually increased from February and reached a peak at mid-April. Then because of the maturation of the citrus foliage, appearance of natural enemies and other factors, the aphid population gradually declined. Only very few of them were found in citrus groves during the summer. However, from September to December the aphid population usually gradually recovered (illustration 1).

During spring and autumn, large colonies of black citrus aphid often attracted a few parasites, such as *Lipolexis gracilis*, *Lysiphlebia japonica*, *Aphelinus mali* and *Lipolexis scutellaris*. *L. gracilis* with a little more abundant than the other species, but none of them was specific to this aphid.

Toxoptera citricida (Kirkaldy) (citrus aphid)

This species occurs in South America, Africa and Asia in forests, parks and gardens, with 9 families of hosts reported from Taiwan. The aphid usually appeared in March, April, October and November, mixed with *Toxoptera aurantii*. Usually it was a major pest of citrus and acted as an important vector by transmitting a virus disease which caused serious damage to citrus. Parasites of the citrus aphid were seldom encountered, during the past 5 years survey, only a very few mummies of *Lipolexis scutellaris* and *Lipolexis gracilis* were reared from the large colonies of citrus aphids.

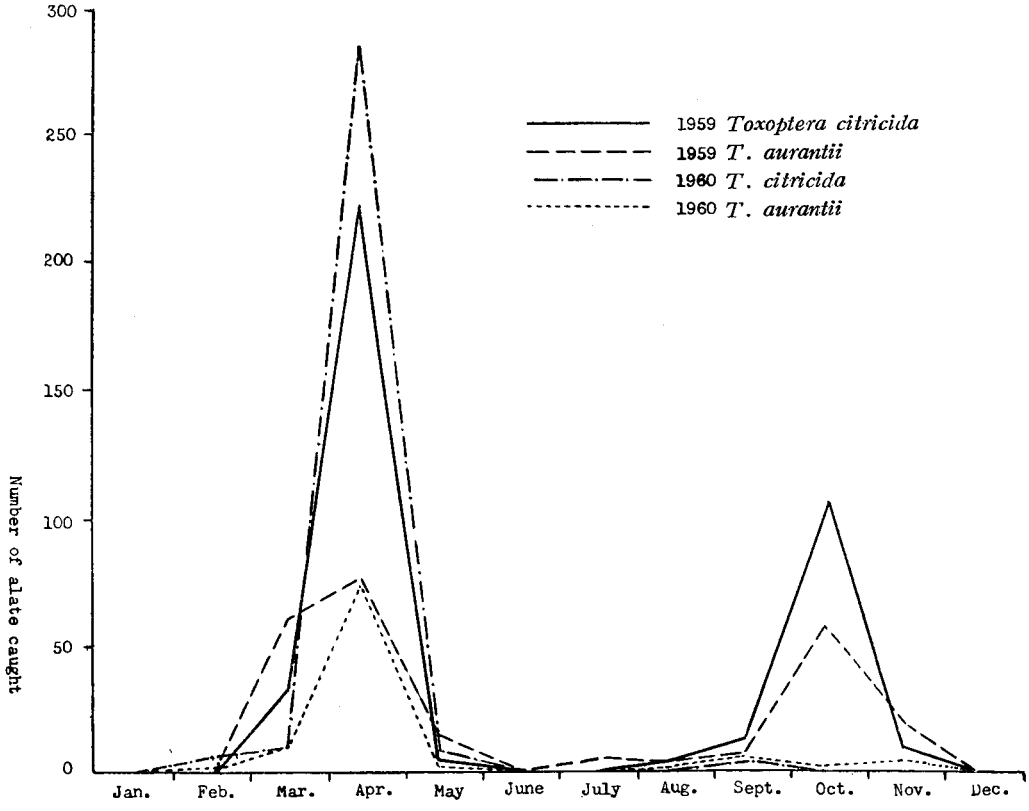


Illustration 1: The seasonal population of *Toxoptera aurantii* and *T. citricida* at Hsinpu, Hsinchu (investigated by Mr. C. C. Tao, 1959-60)

II. Hymenopterous parasites of citrus, vegetables and tobacco aphids

Acyrthosiphon pisum (Harris)

Parasites: *Ephedrus* (*E.*) *plagiator* (Nees); *Trioxys* (*B.*) *formosanus* Liu.

Aphis craccivora Koch
Parasites: *Lipolexis gracilis* Forster; *Lipolexis scutellaris* Mackauer; *Lysiphlebia japonica* (Ashmead).

Aphis glycines Mats.
Parasites: *Trioxys* (*B.*) *communis* Gahan; *Lipolexis gracilis* Forster.

Aphis gossypii Glover
Parasites: *Aphelinus mali* Haldeman; *Ephedrus* (*E.*) *plagiator* (Nees); *Lipolexis gracilis* Forster; *Lysiphlebia japonica* (Ashmead); *Trioxys* (*B.*) *communis* Gahan; *Trioxys* (*B.*) *indicus* Subba Rao & Sharma

Aphis spiraecola Patch
Parasites: *Aphelinus mali* Haldeman; *Ephedrus* (*E.*) *robustus* Liu; *Ephedrus* (*E.*) *plagiator* Nees; *Lipolexis gracilis* Forster; *Lipolexis scutellaris* Mackauer; *Lysiphlebia japonica* (Ashmead); *Trioxys* (*B.*) *citri* Liu.

Brevicoryne brassicae (Lin.)
Parasites: *Diaeretiella rapae* (M'Intosh); *Ephedrus* (*E.*) *persicae* Froggatt.

Cavariella salicicola (Mats.)
Parasites: *Aphidius salicis* Haliday; *Aphelinus* sp.; *Ephedrus* sp.

Dactynotus formosanus (Takahashi)
Parasites: *Ephedrus* (*E.*) *plagiator* (Nees); *Aphelinus* sp.; *Praon dorsale* (Haliday).

Indomegoura indica (van der Goot)
Parasites: *Praon dorsale* (Haliday).

Lipaphis erysimi (Kalt.)
Parasites: *Aphidius gifuensis* Ashmead; *Diaeretiella rapae* (M'Intosh); *Ephedrus* (*E.*) *persicae* Froggatt; *Ephedrus* (*E.*) *plagiator* (Nees).

Longiunguis sacchari (Zehntner)
Parasites: *Aphelinus* sp.; *Lipolexis gracilis* Forster; *Lysiphlebia japonica* (Ashmead): *Ephedrus* (*E.*) *robustus* Liu.

Macrosiphoniella yomenae (Shinji)
Parasite: *Aphidius commodus* Gahan.

Myzus pericae (Sulzer)
Parasites: *Aphidius gifuensis* Ashmead; *Diaeretiella rapae* (M'Intosh); *Ephedrus* (*E.*) *persicae* Froggatt; *Lipolexis gracilis* Forster; *Aphelinus* sp.

Rhopalosiphum maidis (Fitch)
Parasites: *Aphelinus* sp.; *Ephedrus* (*E.*) *robustus* Liu; *Lysiphlebia japonica* (Ashmead); *Lipolexis gracilis* Forster.

Rhopalosiphum nymphaeae (L.)
Parasites: *Aphelinus* sp.; *Trioxys* (*T.*) *auctus* Haliday.

Rhopalosiphum padi (Linne)
Parasite: *Trioxys* (*T.*) *auctus* Haliday.

Semiaphis heraclei (Takahashi)
Parasite: *Lipolexis gracilis* Forster.

Sinomegoura citricola (van der Goot)
Parasites: *Ephedrus* (*E.*) *plagiator* (Nees); *Trioxys* (*B.*) *struma* (Gahan).

Toxoptera aurantii (Boyer de F.)
Parasites: *Aphelinus mali* (Haldeman); *Ephedrus* (*E.*) *plagiator* (Nees); *Lipolexis gracilis* Forster; *Lipolexis scutellaris* Mackauer; *Lysiphlebia japonica* Ashmead; *Trioxys* (*E.*) *toxo-pterae* Takada.

Toxoptera citricida (Kirkaldy)
Parasite: *Lipolexis scutellaris* Mackauer.

Toxoptera odinae (van der Goot)
Parasites: *Ephedrus* (*E.*) *plagiator* (Nees); *Lysiphlebia japonica* (Ashmead).

Uromelan gobonis (Matsumura)
Parasites: *Ephedrus* (*E.*) *plagiator* Nees; *Praon dorsale* (Haliday).

III. Key to the species of hymenopterous parasites of citrus, vegetables and tobacco aphids

1. Antenna 6 segmented; fore wing greatly reduced with distinct oblique speculum; pronotum not extending back to tegular; mesopleurum depressed... 2
   Antenna more than 10 segmented; fore wing not reduced, without speculum; pronotum extending back to tegular; mesopleurum not depressed 3
2. Fore wing (fig. 1, J) with only one row complete oblique setae on basal part of speculum; all coxae and middle femur black; fore femur black with apex yellowish; hind femur white color .....*Aphelinus mali*
   Fore wing (fig. 5, A) with several oblique rows of setae on basal part of speculum; coxae black except fore coxa brown; all femora yellow color ..... *Aphelinus* sp.
3. Cubitus I absent, first cubital cell and median cell fused 4
   Cubitus I present, first cubital cell and median cell separated 7
4. First and second intercubital veins absent (fig. 1, B); propodeum not carinated; pupation took place outside of its host body, forming a cocoon under the skin of host; usually defined as primary parasite of *Dactynotus*, *Indomegoura* and *Uromelan* aphids .....*Praon dorsale*
   First and second Intercubital veins present; propodeum distinctly carinated; pupation took place inside of its host body 5
5. The confluent point of notauli on mesoscutum with a distinct and deep fovea; abdominal tergite I (fig. 2, G) broad, slightly longer than wide .... *Ephedrus* (*E.*) *persicae*

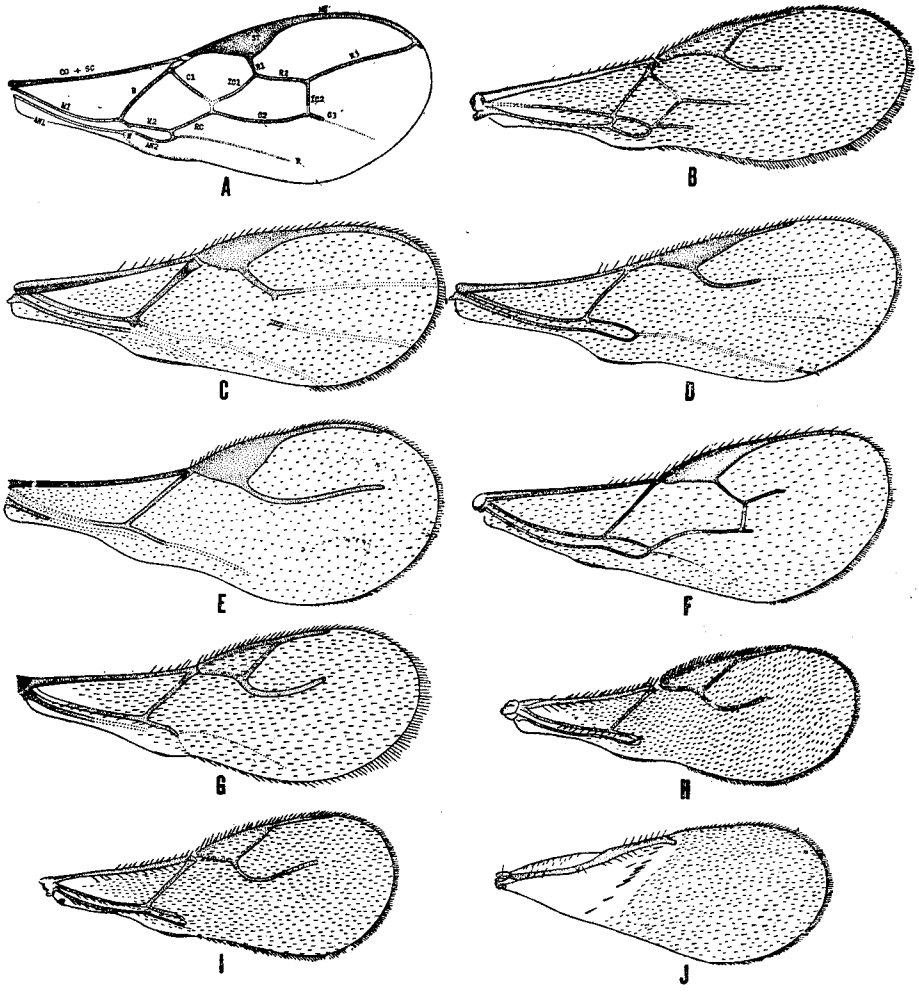


Fig. 1. Fore wing: *Ephedrus* (*E.*) *plagiator* (A); *Prcon dorsale* (B); *Lysiphlebia japonica* (C); *Diaeretiella rapae* (D); *Liposlexis gracilis* (E); *Aphidius gifuensis* (F); *Trioxys* (*B.*) *communis* (G); *Trioxys* (*B.*) *formosanus* (H); *Trioxys* (*B.*) *citri* (I); *Aphelinus mali* (J).

The confluent point of notauli without any fovea on mesoscutum; abdominal tergite I (fig. 2, F) at least twice as long as wide 6

6. Ovipositor sheath (fig. 2, L) slender and straight, about 4 times as long as wide..... *Ephedrus* (*E.*) *plagiator*

Ovipositor sheath (fig. 2, K) more or less stout, gradually narrowing towards its apex, middle part about 3 times as long as wide.....*Ephedrus* (*E.*) *robustus*

7. Fore wing (fig. 1, F) with distinct recurrent vein, discocubital cell completely closed; first and second radial abscissae almost equal in length; antenna with 13-18 segments in female 8

Fore wing (fig. 1, C) with entirely effaced recurrent vein, discocubital cell open below, first radial abscissa longer than second radial abscissa, or the latter one absent; antenna with 12-14 segments in female 10

8. Antenna 13-14 segmented in female ..... *Aphidius salicis*
   Antenna 16-18 segmented in female 9
9. Ovipositor sheath (fig. 2, M) stout, never twice as long as its width; antenna 17-18 segmented; usually defined as primary parasites of *Myzus* and *Lipaphis* aphids ..... *Aphidius gifuensis*
   Ovipositor sheath (fig. 2, N) slender, more than twice as long as its width; antenna 16-17 segmented in female; usually defined as primary parasites of *Macrosiphoniella* aphids ..... *Aphidius commodus*
10. Metacarpus much longer than stigma, cubitus partially and second intercubitus present; propodeum (fig. 2, J) with effaced bifurcating central carinae ..... *Lysiphlebia japonica*
    Metacarpus less than, or as long as stigma, cubitus entirely and second intercubitus absent; propodeum with distinct bifurcating central carinae... 11
11. Last abdominal sternite of female without prongs 12
    Last abdominal sternite of female with prongs 14
12. Ovipositor sheath stout; radius (fig. 1, D) reaching nearly to the mid-way of metacarpus; areola (fig. 2, H) narrow and small ..... *Diaeretiella rapae*
    Ovipositor sheath slender and curved downwards; radius (fig. 1, E) reaching the apex of metacarpus; areola (fig. 2, I) broad and large 13
13. Abdominal tergite I (fig. 2, A) with distinctly and strongly bifurcating central carinae; body mostly brown or dark brown ..... *Lipolexis gracilis*
    Abdominal tergite I (fig. 2, B) without bifurcating central carinae; body mostly yellowish ..... *Lipolexis scutellaris*
14. Tergite I (fig. 2, C) stout about twice as long as wide at spiracles, with only spiracular tubercles; usually defined as primary parasites of *Rhopalosiphum* aphids ..... *Trioxys* (*T.*) *auctus*
    Tergite I slender, more than twice as long as wide at spiracles; with 1st and 2nd lateral tubercles 15
15. Distance between 1st and 2nd lateral tubercles of tergite I distinctly shorter than distance between 2nd spiracular tubercle and posterior margin of the tergite (fig. 2, D); with only 2 hairs right behind the 2nd tubercle; first flagellar segment about 2.2 times as long as wide..... *Trioxys* (*B.*) *communis*
    Distance between 1st and 2nd lateral tubercles longer than distance between 2nd tubercle and posterior margin of the tergite (fig. 2, D); with sparse hairs on its posterior part; first flagellar segment of antenna about 3 times as long as wide... 16
16. Apical part of ovipositor sheath gradually tapering toward apex and about 0.33 of basal part; tergite I (fig. 2, D) about 4 times as long as wide at spiracles, distance between 1st and 2nd lateral tubercles longer than twice the distance between 2nd tubercle and posterior margin of the tergite ... . *Trioxys* (*B.*) *struma*

Apical part of ovipositor sheath almost straight and abruptly narrow at apex, and about 0.3 to subequal of basal part; tergite I about 3.0 as long as wide at spiracles, distance between 1st and 2nd lateral tubercles as long as, or less than 2.0 the distance between 2nd tubercle and posterior margin of the tergite.....17

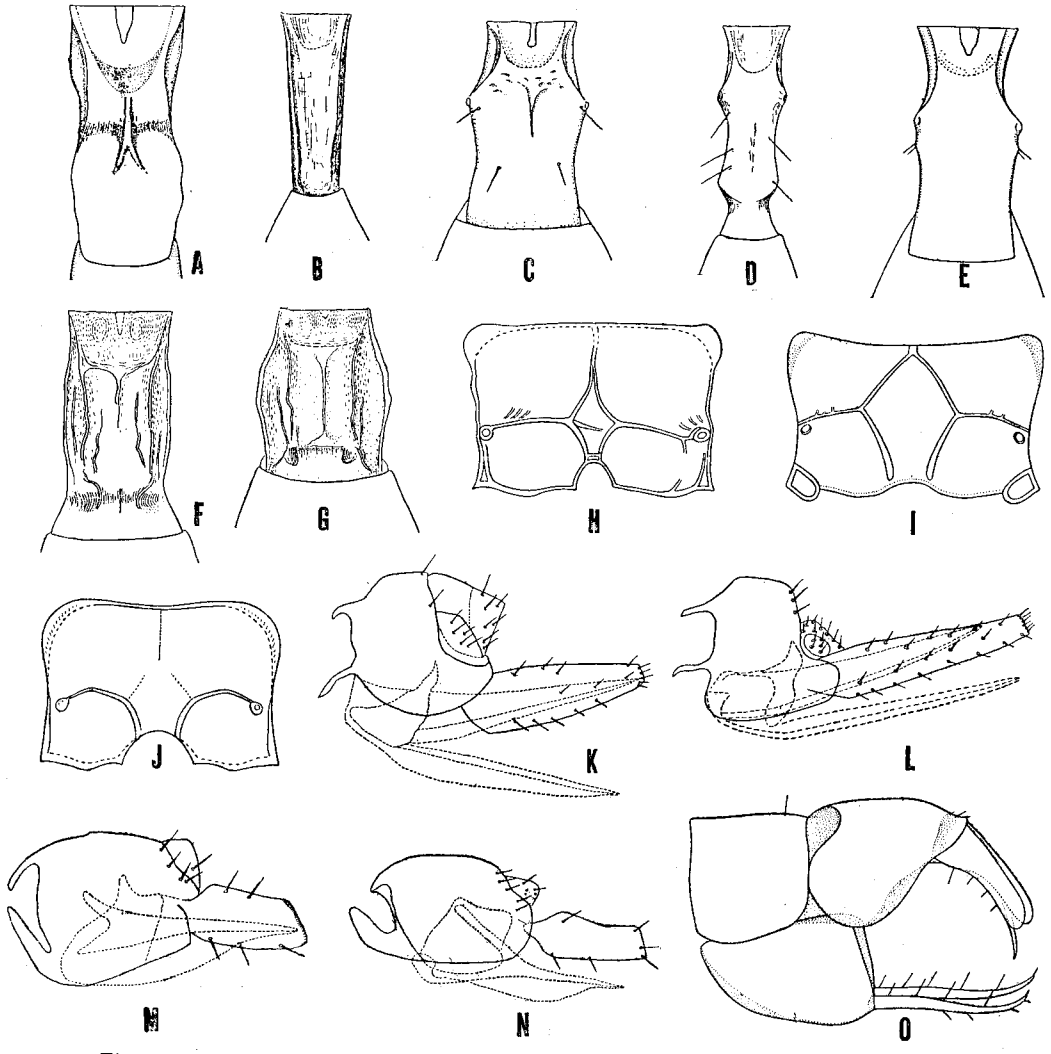


Fig. 2. Tergites, propodeums and ovipositor sheaths: Tergite, *Lipolexis gracilis* (A); *Lipolexis scutellaris* (B); *Trioxys* (*T.*) *auctus* (C); *Trioxys* (*B.*) *struma* (D); *Trioxys* (*B.*) *communis* (E); *Ephedrus* (*E.*) *robustus* (F); *Ephedrus* (*E.*) *persicae* (G). Propodeum, *Diaeretiella rapae* (H); *Lipolexis gracilis* (I); *Lysiphlebia japonica* (J). Ovipositor sheath, *Ephedrus* (*E.*) *robustus* (K); *Ephedrus* (*E.*) *plagiator* (L); *Aphidius gifuensis* (M); *Aphidius communis* (N); *Trioxys* (*B.*) *communis* (O).

17. Pterostigma (fig. 1, H) about 0.33 longer than radial vein; anal prong with 5 hairs on dorsal margin; propodeum with longer laterally oblique carinae ..... *Trioxys* (*B.*) *formosanus*
Pterostigma (fig. 1, I) almost as long as radial vein; anal prong with 4 hairs on dorsal margin; propodeum without laterally oblique carinae.....18
18. Face about 0.45 times as wide as head; tergite I with distinct 1st and 2nd tubercles, the interspace of 2nd lateral tubercles distinctly wider than that of first lateral tubercles .....*Trioxys* (*B.*) *citri*
Face about 0.36 times as wide as head; tergite I with slightly prominent 1st and 2nd lateral tubercles, the interspace between 2nd lateral tubercles almost as wide as that between first lateral tubercles.....*Trioxys* (*B.*) *toxopterae*

IV. Hymenopterous parasites of aphids on citrus, vegetables and tobacco and other plants

Aphelinus mali (Haldeman)

Host aphids: *Aphis gossypii* Glover on *Hibiscus* sp., *Colocasia esculenta* Schott., *Luffa cylindrica* Roem. and *Psidium guajava* Linn.; *Myzus persicae* (Sulzer) on *Brassica* sp., *Brassica oleracea* Linn. (cabbage), *Prunus persica* Batsch (peach) and *Capsicum annum* Linn. (sweet pepper); *Toxoptera aurantii* (Boyer de F.) on *Citrus* sp.; *Aphis spiraecola* Patch on *Glochidion hongkongense* Mullagr, *Spiraea* sp. and *Citrus* sp.

Aphelinus sp.

Host aphids: *Cavariella araliae* Takahashi on *Aralia decaisneana* Llanco; *Dactynotus formosanus* (Takahashi) on *Lactuca sativa* Linn.; *Longiunguis sacchari* (Zehnt.) on *Zea mays* Linn.; *Myzus persicae* (Sulzer) on *Brassica* sp. *Rhopalosiphum maidis* (Fitch) on *Zea mays* Linn. and *Triticum vulgare* Vill., *Rhopalosiphum nymphaeae* (Linne) on *Sagittaria sagittifolia* Linn.

Aphidius commodus Gahan

Host aphids: *Macrosiphoniella yomenae* (Shinji) on *Artemisia vulgaris* Linn. var *indica* Maxim., *Macrosiphoniella formosartemisiae* Takah. and *Macrosiphonilla yomogifoliae* (Shinji) on *Artemisia* sp.

Aphidius gifuensis Ashmead

Host aphids: *Capitophorus* sp. on unknown plant; *Macrosiphum rosaeibarae* Mats. on *Rosa* sp.; *Lipaphis erysimi* (Kalt.) on *Brassica cernua* Forbes et Hemsl. (mustard) and *Brassica pekinensis* Rupr. (Paitsai); *Myzus persicae* (Sulzer) on *Brassica* sp., *Raphanus sativus* Linn. (radish), *Prunus persica* Batsch. (peach), *Lycopersicum esculetum* Mill (tomato), *Brassica campestris* Linn. (rape green), *Brassica oleracea* Linn. (cabbage), *Brassica pekinensis* Rupr. (paitsai), *Capsicum annum* Linn. (sweet pepper), *Solanum nigrum* Linn. (egg plant), *Chrysanthemum coronarium* Linn. and *Nicotiana tabacum* Linn. (tobacco).

Aphidius salicis Haliday

Host aphids: *Cavariella araliae* Tak. on *Aralia* sp., *Cavariella salicicola* (Mats.)

on *Salix* sp.

Diaeretiella rapae (M'Intosh)

Host aphids: *Brevicoryne brassicae* (Linn.) on *Brassica oleracea* Linn. and *Brassica rapa* Linn.; *Lipaphis erysimi* (Kalt.) on *Brassica cernua* Forbes et Hemsl. and *Myzus persicae* (Sulzer) on *Brassica pekinensis* Rupr. and *Brassica* sp.

Ephedrus (E.) persicae Froggatt

Host aphids: *Aphis gossypii* Glover on *Chrysanthemum* sp. and *Hibiscus* sp.; *Aphis spiraecola* Patch on *Spiraea cantonensis* Lour.; *Hyalopterus pruni* (Fabricius) on *Prunus persicae* Batsch.; *Lipaphis erysimi* (Kalt.) on *Brassica* sp.; *Myzus persicae* (Sulzer) on *Brassica* sp., *Hibiscus* sp., *Prunus persica* Batsch.; *Tinocallis ulmi-parvifoliae* Matsumura on *Ulmus* sp.

Ephedrus (E.) plagiator (Nees)

Host aphids: *Aphis gossypii* Glover on *Citrus* sp.; *Aphis spiraecola* Patch on *Spiraea* sp; *Hyperomyzus lactucae* (Linn.) on *Lactuca sativa* Linn. and *Sonchus* sp.; *Dactynotus formosanus* (Takahashi) on *Lactuca sativa* Linn.; *Macrosiphum rosaeibarae* Mats. on *Rosa* sp.; and *Sinomegoura citricola* (van der Goot) on *Murraya paniculata* Jack.; *Myzus persicae* (Sulzer) on *Nicotiana* sp. and *Brassica* sp.; *Toxoptera odinae* (van der Goot) on *Viburnum suspensum* Lindley; *Acyrthosiphon pisum* (Harris) on *Medicago sativa* Linn. (alfalfa).

Ephedrus (E.) robustus Liu

Host aphids: *Aphis spiraecola* Patch on *Citrus* sp.; *Longiunguis sacchari* (Zehntner) on *Holcus sorghum* Linn. (sorghum).; *Rhopalosiphum maidis* (Fitch) on *Zea mays* Linn.

Lipolexis gracilis Forster

Host aphids: *Aphis gossypii* Glover on *Hibiscus* sp., *Colocasia esculenta* Schott., *Luffa cylindrica* Roem. and *Psidium guajava* Linn.; *Aphis craccivora* Koch on *Vicia faba* Linn.; *Aphis glycines* Mats. on *Glycine max* (Linn.) Merrill; *Myzus persicae* on *Prunus persicae* Batsch. (peach), *Lycopersicum esculentum* Mill. (tomato) *Bassica campestris* Linn. (rape green); *Aphis spiraecola* Patch and *Toxoptera aurantii* (Boyer de F) on *Citrus* sp.

Lipolexis scutellaris Mackauer

Host aphids: *Aphis craccivora* Koch on *Dolichos lablab* L.; *Aphis spiraecola* Patch, *Toxoptera aurantii* (Boyer de F.) and *Toxoptera citricida* (Kirk.) on *Citrus* sp.

Lysiphlebia japonica Ashmead

Host aphids: *Aphis gossypii* Glover on *Hibiscus* sp., *Colocasia esuclenta* Schott. and *Psidium guajava* Linn. (guava); *Aphis spiraecola* Patch on *Citrus* sp.; *Aphis craccivora* Koch on *Dolichos lablab* Linn.; *Longiunguis sacchari* (Zehn.) on *Holcus sorghum* Linn. (sorghum); *Toxoptera odinae* (v. d. Goot) on unknown plants.

Praon dorsale Haliday

Host aphids: *Dactynotus formosanus* (Takahashi) on *Lactuca sativa* Linn.; *Indomegoura indica* (v. d. Goot) on *Hemerocalis fulva* Linn.; *Uromelan gobonis* (Mats.) on *Carthamus tictorius* L.

Trioxys (B.) communis (Gahan)

Host aphids: *Aphis glycines* Mats. on *Glycines max* (Linn.) Merrill; *Aphis gossypii* Glover on *Hibiscus* sp., *Colocasia esculenta* Schott., *Luffa cylindrica* Roem. and *Psidium guajava* Linn. (guava); *Rhopalosiphum* sp. on *Yerbena phlogiflora* Cham.

Trioxys (B.) citri Liu

Host aphid: *Aphis spiraecola* Patch on *Citrus* sp.

Trioxys (B.) formosanus Liu

Host aphid: *Acyrthosiphon pisum* (Harris) on *Vicia faba* Linn.

Trioxys (B.) indicus Subba Rao & Sharma

Host aphid: *Aphis gossypii* Glover on *Hibiscus* sp.

Trioxys (B.) struma (Gahan)

Host aphid: *Sinomegoura citricola* (v. d. Goot) on *Cinnamomum camphora* Sieb. (camphor) and *Citrus* sp.

Trioxys (B.) toxopterae Takada

Host aphid: *Toxoptera aurantii* (Boyer) on *Citrus* sp.

Trioxys (T.) auctus Haliday

Host aphids: *Rhopalosiphum nymphaeae* (Linn.) on *Sagittaria sagittifolia* Linn.; *Rhopalosiphum padi* (Linne) on unknown plant.

V. Biology of the major parasites of citrus, vegetables and tobacco aphids

Aphidius gifuensis Ashmead (fig. 3, A-F)

Adult (fig. 3, A) is easily recognized by its yellowish brown color, fore wing with discocubital cell closed, 1st and 2nd abscissae of radius subequal in length, propodeum with strongly carinated narrow areola and antenna usually 17 segmented, rarely 18 segmented in female. It is a parasite of *Myzus persicae* and *Lipaphis erysimi*.

The parasite occurred almost all year round except in case of aestivation from July through September. It appears to be an effective parasite of *Myzus persicae* but is occasionally found in *Lipaphis erysimi* in Taiwan. It has been reported only in the Oriental region. We assume that it may be a promising biological control agent of peach aphid, if it is introduced to peach aphid distributed areas having the similar climatic condition as Taiwan.

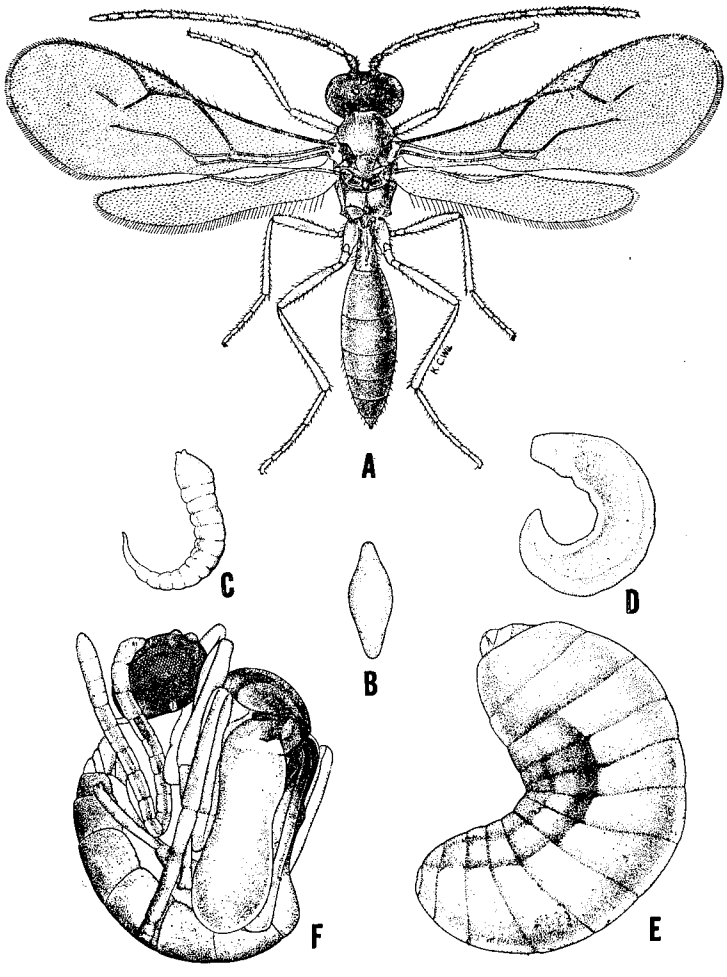


Fig. 3. *Aphidius gifuensis*: adult (A); egg (B); 1st instar larva (C); 2nd instar larva (D); 3rd instar larva (E); pupa (F).

Immature stages: *Egg* (fig. 3, B) transparent, spindle-shaped, about 0.06-0.09 mm in length. Larval stage can be divided into three instars by the shapes of head and cauda. *First instar* (fig. 3, C) with body transparent; head distinct with visible mandibles; body 13 segmented with long cauda which is about as long as its 3 preceding segments combined. *Second instar* (fig. 3, D) with visible mandibles and head; body segments indistinct, without cauda. *Third instar* (fig. 3, E) with skeletal mandible. *Prepupa* similar to third instar larva but with shorter body and thicker integument; fat bodies inside its body are clearer. *Pupa* (fig. 3, F) exarate with visible appendages and yellow to greenish yellow color.

Life cycle: *Aphidius gifuensis* usually takes 8-10 days to complete one generation; egg stage lasted 2-2.5 days; first, second and third instar of larvae lasted half to 1 day, 1 to 2 days and 2 to 2.5 days respectively; pupal stage lasted 2-3 days. Host aphids always died shortly before the third instar larva had developed in its body cavity.

Host aphid: Immediately after the aphid was parasitized, it appeared even more reluctant than the unparasitized one. Its color gradually changed from green to yellowish, somewhat translucent at the beginning. After a few days, it turned fuscous and then the shape of mummy became oval and bulky. Its average size was about 2.7 mm in length and 1.6 mm in width.

Emergence: During emergence, the parasite emerged from a cocoon inside the body of the mummified aphid by using its mandibles to chew around the place between cornicles or in front of the cauda of mummy. Soon after emergence, the parasite is vigorous and lively. Its wings will fully expand within a few seconds and it always cleans antennae, wings and legs by using its mouthparts. When honey was visible, the parasite always fed quietly on it for a short period. It usually takes 4 to 6 days or longer from the formation of an aphid mummy to its parasite emergence.

Mating: When a sexually mature female appeared, the male was immediately aware of her presence. The male would approach the female and played his antennae all over the female and waved from side to side to catch the thorax of female with its legs, then they would mate. The copulation usually lasted from 35 to 55 seconds. If the female had already mated, she always bent her abdomen under and refused.

Oviposition: The female played her antennae all over the host aphid when she contacted it. Immediately, she bent her abdomen down and quickly probed into it with her ovipositor. If the ovipositor could not insert, she would draw it back and move around the aphid seeking for another suitable position. Occasionally, she might strike again on the same area until the ovipositor was inserted. After the eggs are deposited, the parasitized aphid gradually becomes bulky and oval in shape.

Reproductive capacity: 20 new emerging female parasites were divided into two groups, each 10 individuals placed in a small glass tube about 2×9 cm in size. One group was fed with honey and water, the other group with water only. These were confined without a host and retained their full complement of eggs. After three days of feeding, the specimens were dissected for counting the number of eggs in their oviducts as table 1.

The number of fully developed eggs in the left (L) and right (R) oviducts of a female parasite were different (table 1). The total number of eggs per female was from 113 to 240 (average 176). If an adequate number of suitable hosts were provided, the females were capable of laying their full complement of eggs. The average reproductive capacity for the species is thus about 176-fold. Furthermore, table 1 also shows that feeding the parasites on honey or water did not affect the number of eggs produced.

Table 1. Number of eggs from 3-day old females of *A. gifuensis*.

Specimen dissected			Number of eggs in oviducts										average
Feeding water only	Full developed eggs in oviduct	R	62	68	90	96	108	86	110	79	62	82	84.3
		L	64	61	89	144	113	97	94	98	51	93	90.4
	Total eggs per ♀		126	129	179	240	221	183	204	177	113	175	174.7
Feeding honey & water	Full developed eggs in oviduct	R	89	95	66	63	76	98	72	133	98	91	88.1
		L	92	101	92	52	97	90	63	102	85	76	85.0
	Total eggs per ♀		181	196	158	115	173	188	135	235	183	167	173.1

Host size preference: To obtain information about the host size preference of the parasite, a large number of various stages of parasite-free green peach aphids were placed on radish in pots. They were then moved into a fine mesh screened cage for at least 24 hours to permit the aphids to spread over the plants. After 2 days, 4 parasites (3♀, 1♂) were released into the cage and allowed to oviposite freely for 24 hours. After their deposition, the colonies of aphids were immediately removed from the plants and segregated into the different instars. They were placed on individual plants and isolated in separate cages. After the host aphids mummified, they were all collected and kept in a small glass tube for emergence. The results are shown in table 2.

Table 2. Ovipositional preference of *A. gifuensis* to its host.

Test no.	Item	Aphid instar				Adult alate & apterous(indiv.)
		I	II	III	IV	
1	No. of aphids	34	61	17	26	26
	Aphids parasitized	4	8	4	10	0
	Percent parasitism (%)	11.76	13.11	23.53	38.46	0
2	No. of aphids	39	42	34	28	7
	Aphids parasitized	4	4	8	10	0
	Percent parasitism (%)	10.25	9.52	23.52	35.71	0
3	No. of aphids	57	98	63	21	35
	Aphids parasitized	2	1	5	2	2
	Percent parasitism (%)	3.5	1.02	7.93	9.52	5.71
4	No. of aphids	95	157	84	36	96
	Aphids parasitized	3	7	9	17	9
	Percent parasitism (%)	3.16	4.45	10.71	47.22	9.37
	Average of percent parasitism (%)	7.16	7.02	16.42	32.72	3.77

The above table shows that the third and fourth instar aphids were apparently preferred by the parasite.

Maintenance of parasites: To find the suitable temperature for maintaining the living immature parasites. Right after parasitization the aphids were translucent in appearance. The mummified aphids holding the prepupal stage of *A. gifuensis* inside their body were kept at 5°C, 10°C, 25°C and 30°C temperature respectively. Each group of mummies was kept in a 4×1 cm transparent plastic box. We found that 5°C could maintain the prepupal stage of the parasite for at least 50 days. Those mummies being stored at 5°C for 50 days were moved into 10°C for one day and then exposed in 22°C for emergence, usually about 44% of mummies emerged. In the other treatment, parasite was directly moved from 5°C to 22°C after 46 days storage, when the percentage of emergence was 18% only. It was evidently proved that a gradually changing temperature was more favorable for parasite's maintenance. The intention of keeping the parasite under 10°C was not to induce diapause but to delay the process of its development. They could be maintained 17-20 days longer than those kept under the temperature of 25°C and allowed to emerge at 30°C.

Table 3. Percentage of emergence under different temperature (1968)

Temperature	Total no. of mummies (indiv.)	Storage period (days)	Pupa-adult period (days)	Number of parasites (indiv.)	Percentage of emergence (%)
5°C	141	50	6.0	73	52
10°C	130	0	17.5	99	76
25°C	110	0	5.0	83	73

Fecundity: One mated female of *A. gifuensis* was released into a cage screened with a fine mesh cloth, which contained a large number of parasite-free green peach aphids under 14-hour fluroescent light daily. The female was allowed to oviposit freely. About 5-7 days later, an average of 101 individuals of mummified aphids were collected.

Longevity of adult: During laboratory rearing, honey was used as an adult diet. The pure honey was usually too sticky and often trapped the adults, therefore, a half honey and a half water mixture was better for feeding the parasite. Our observations showed, the temperature is the most important factor which influences the longevity of the adult. Different temperature treatments such as 10°C, 20°C and 30°C were used for rearing the adults. The results showed that the treatment under 10°C was ideal to maintain the adult's life in the laboratory. Longevity averaged 29 days as shown in the following table.

Table 4. Longevity of adult influenced by temperature

Temperature	parasite (indiv.)	Shortest life (days)	Longest life (days)	50% Deaths (days)
10°C	21	23	30	29
20°C	16	3	9	9
31°C	14	2	3	2.5

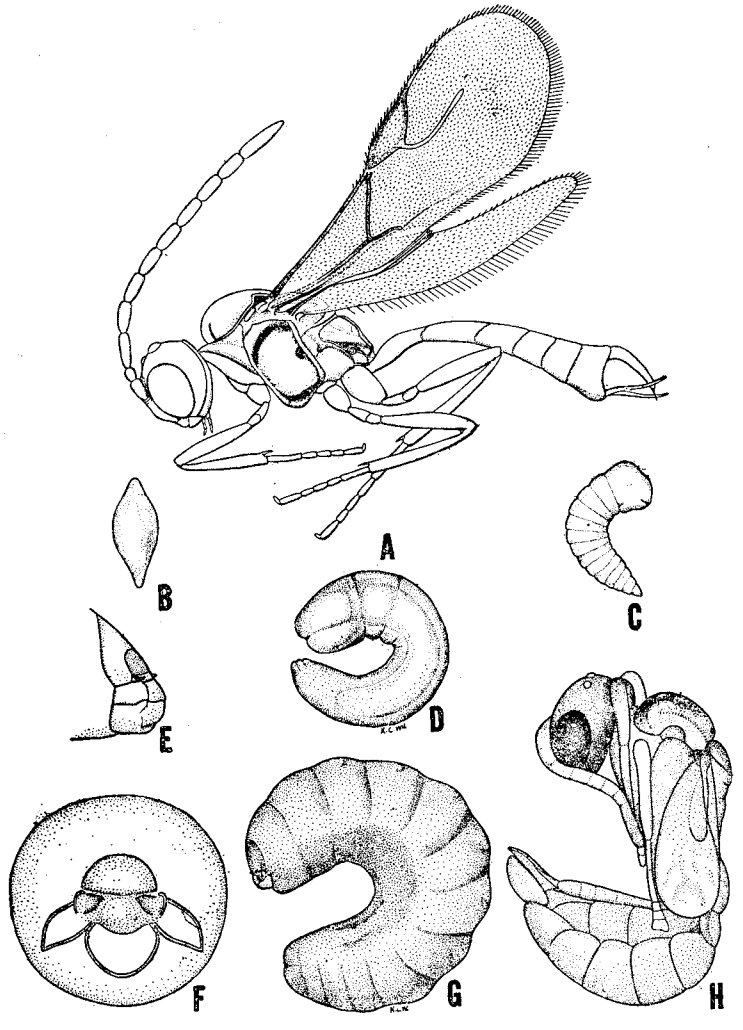


Fig. 4. *Trioxys* (*B.*) *communis*: adult (A); egg (B); 1st instar larva (C); 2nd instar larva (D); mouthparts, lateral and frontal view of 3rd instar larva (E, F); 3rd instar larva (G); pupa (H).

Trioxys (B.) communis (Gahan) (fig. 4, A-H)

Adult (fig. 4, A) may be easily recognized by its blackish brown body, the discocubital cell is opened, the cubital and intercubital veins are absent. It differs from its related species by having less distinct 1st and 2nd spiracular tubercles on the tergite, and the distance between the two tubercles is shorter than the distance between the 2nd tubercle and posterior margin of the tergite.

This parasites occurred almost all year round in Taipei area except during the unfavorable season from January to April. It usually became very abundant in August and October (fig. B), and was a very specific and effective parasite of *Aphis gossypii*. Consequently, it may be regarded as a very valuable biological control agent for cotton aphid. Some biological characteristics of *T. (B.) communis* were studied as follows:

Immature stages: *Egg* (fig. 4, B) transparent, spindle-shape, about 0.072 mm in length. *First instar larva* (fig. 4, C) molted about 2 or 3 days after the egg was deposited. It was milky white, somewhat transparent, consisting of a head and 13 body segments gradually tapering toward its posterior end; head longer than the three thoracic segments combined, about 0.5 mm in average length. *Second instar larva* (fig. 4, D) molted about 3 or 4 days after the egg was deposited. It was yellowish, with indistinct abdominal segmentation; head and first thoracic segment not clearly defined; body smooth about 0.9 mm in average length; oral lobe rather distinct. *Third instar larva* (fig. 4, G) molted about 5-8 days after the egg was deposited. It was greenish yellow except mandible dark brown, mouthparts consist (fig. 4, E-F) of three lobes and one pair of smooth, sharply pointed teeth, body very rugose with distinct segmentation, always U-shaped, averaging about 1.3 mm in length. Cocoon formed in the abdomen of the dead host aphid. *Prepupa* was very similar to the third instar larva but with shorter body and much looser integument, fat bodies within the body are visible, both ends of body are swollen and bluntly pointed. *Pupa* (fig. 4, H) exarate, with very fine segmentation, soft fleshy and light yellowish in color at the beginning. Thereafter, appendages appeared and the fleshy appearance disappeared. Pigment of eyes and b dy gradually becomes apparent.

Life cycle: *Trioxys (B.) communis* usually took 8-12 days to complete one generation. Temperature and humidity influenced the development of immature stages which occurred inside the aphid body.

Host aphid: After the larva of the parasite hatched and gradually fed on its host aphid, the parasitized aphid showed no difference in appearance. The aphid was killed when the third instar larva of the parasite almost entirely occupied the abdominal cavity of the host aphid. Thereafter, the parasitized aphid gradually become more and more swollen in appearance. Finally it became mummified and pale brown in color.

Mating: The mating behavior of this species was very similar to that of the preceding species. Copulation lasted 15 to 20 seconds. Females mated only once during their life time but males mated often.

Oviposition: The female parasite seemed able to feel the presence of the host aphid by sensory contact, odour and sight. The presence of an aphid colony was probably detected by the odour of honey dew from the aphid (Schlinger, 1961). The female approached the aphid and raised her wings to a vertical position, rapidly vibrated them and played her antennae. When contact with the aphid was made, the female parasite quickly struck at it with its ovipositor in the manner of other *Trioxys* wasps. Sometime the ovipositor insertion was not successful and caused the aphid to move. The parasite would back away and search for another position. She might strike again in the same area and repeatly oviposit. The female parasite was apparently unable to distinguish whether the aphid had been parasitized by herself previously or not.

Longevity of adult: It depended on the temperature, humidity and food. In our laboratory feeding, we fed adults with honey plus 50% water. The longevity of the adult was about 6-10 days in insectary under 22°C and 60-80% R. H.

Reproductive capacity: Ten pairs of newly emerged parasites were used for testing their reproductive capacity in a small glass tube and fed with honey plus 50% water. After three days, the females were dissected and the number of mature eggs in their right (R) and left (L) oviducts were counted as the follows:

Table 5. Egg counts for 3-day old females of *Trioxys (B.) communis*

Specimen dissected		1	2	3	4	5	6	7	8	9	10	Average
Full developed eggs in oviduct	R	89	84	35	89	49	91	69	91	64	93	75.2
	L	79	61	79	78	82	72	101	75	85	68	79.8
Total eggs per ♀		186	145	114	165	131	163	170	166	149	161	155.0

The number of fully developed eggs in two oviducts were found to be different. The same results were found in *Aphidius gifuensis*. The total number of eggs per female ranged from 114 to 186 (155 in average), which is less than of *A. gifuensis*.

Seasonal occurrence: *Trioxys (B.) communis* usually occurred from May to November in Taiwan. Their population was closely related to temperature, humidity, populations of host aphid and secondary parasites. According to our collecting data, it is very abundant in August and October in Taipei area (illustration 2).

Host size preference: The numerous parasites of *Trioxys (B.) communis* were released into a screen cage which contained large colonies of cotton aphids for use in laboratory inoculation (24°C). The results showed that 70% and 64.2% parasitism of *T. (B.) communis* occurred in the 3rd and the 4th instar larvae respectively in 76±3°F.

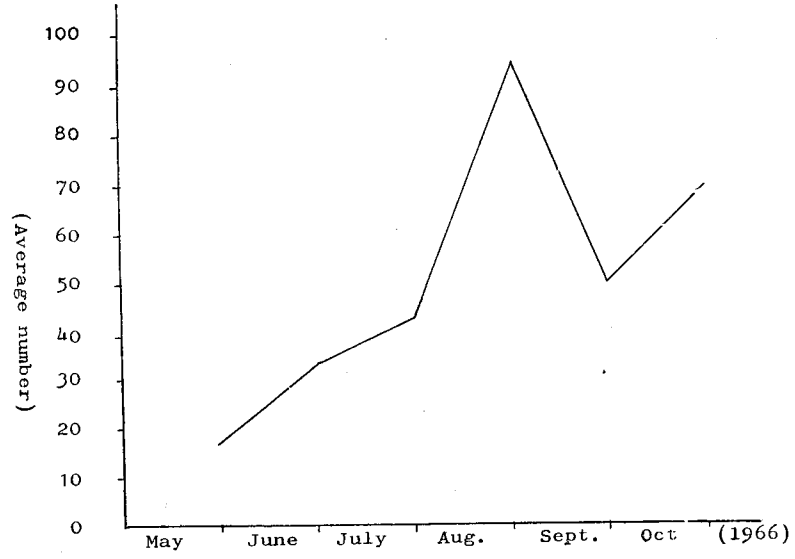


Illustration 2: Seasonal occurrence of *Trioxys* (*B.*) *communis* in Taipei area (1966).

Table 6. Percentage of parasitization and host-instar preference (1966)

Aphid instar	Aphids	Mummies	Parasites	Parasitization (%)	Parasite emerg. (%)
III	500*	365	259	73.0	70.0
IV	300**	182	117	60.6	64.2

*10 sets of 50 aphids each. **6 sets of 50 aphids each.

Sex ratio: The fertilized female produces both males and females. The virgin female produces unfertilized eggs which develop only into males. For this reason, the sex ratio is rather variable. Observation on once mated females in laboratory shows the sex ratio in the following table 7.

Aphelinus sp. (fig. 5, A-C)

Adult (fig. 5, A) distinctly differs from *Aphelinus mali* by having several oblique rows of setae on the triangular speculum of the fore wing. The morphological characteristics are very similar to *Aphelinus flavipes.* However we are not able to determine the species at present.

The parasite occurred very commonly from May to October in Taipei area. Its population was as low as 0.5-10% in the favorable season. In winter they were hardly to be found on the field and no diapause has been found so far.

The bionomics observations of this species bred on *Myzus persicae* were recorded as follows:

Table 7. Sex ratio of *Trioxys* (*B.*) *communis* (1966)

Number	Number of parasites ♀	♂	Sex ratio
1	6	11	0.35 : 0.65
2	10	16	0.38 : 0.62
3	20	13	0.80 : 0.20
4	16	19	0.47 : 0.53
5	12	18	0.40 : 0.60
6	26	6	0.70 : 0.30
7	31	13	0.70 : 0.30
8	10	10	0.50 : 0.50
9	9	8	0.52 : 0.48
10	4	6	0.40 : 0.60
11	2	4	0.33 : 0.67
12	9	7	0.56 : 0.44
13	25	10	0.71 : 0.29
14	7	24	0.20 : 0.80
15	13	13	0.50 : 0.50
16	4	5	0.40 : 0.60
Total	204	183	0.52 : 0.48

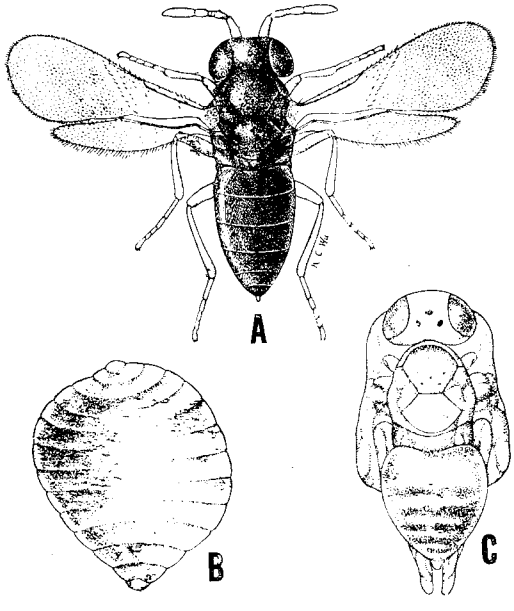


Fig. 5. *Aphelinus* sp.: adult (A); larva (B); pupa (C).

Immature stages: *Egg* translucent, cylindrically ovate and slightly arched, about 0.111×0.047mm to 0.158×0.063mm in size. *Larva* (fig. 5, B) usually hatched within 48 hours after egg deposited. *First instar larva* about 0.285×0.156 mm, somewhat translucent, spindle-shaped. *Second and third instar* larva possessed no distinct features, so it is difficult to determine the number of instars. On the third day after the larva hatched from the egg it was about 0.6×0.5 to 0.7×0.6 mm in size and was lemon-shaped with a distinct head and cauda. Its mandibles were visible and sclerotized. At the same time, the color of its host aphid changed gradually from translucent to black within 7 to 9 hours. When the host aphid died at the fourth day after the eggs hatched, the mature larva occu-

pied almost the entire abdominal chamber. *Pupa* (fig. 5, C) appeared about 5 days after the larva hatched, its head, thorax and abdomen and some important appendages were clearly visible. About two days later, it was pigmented with eye reddish, head and thorax dark brown, antenna pale yellow, abdominal segments distinguishable as yellow tinged with black.

Host size preference: The female parasite mostly preferred the 2nd and 3rd instars aphids as its host (see table 8), it was very often that the 4th instar or adult aphid was attached to the antenna of the female parasite. It always wagged and elevated its abdoments to reject the female parasite's pricking.

Table 8. The nymphal stage of *Myzus persicae* selected by *Aphelinus* sp. for oviposition

Instar	1st	2nd	3rd	4th & adult	Total
Peach aphid parasited	10.0	415	298	34.0	748
% parasited within different stage of peach aphid	1.3	55	39	4.7	100

Mating behavior: When the male felt the presence of the female, he always raised his wings to a vertical position, rapidly vibrated, then flew and trotted towards her. He climbed on her back and flexed his abdomen, meanwhile the female and the male attached each other with their antennae. Then they moved backwards a little (like in a sitting pose) to perform the copulation which usually lasted an average of 18 seconds.

Oviposition behavior: The *Aphelinus* species usually was attracted by a stimulus given from its host plant, then she flew and trotted towards the plant and aimlessly wandered on the leaves. The female about 2-3 mm away from the aphid was still able to detect its presence. The oviposition behavior of *Aphelinus* was observed to be very different from the Aphidiid. Female *Aphelinus* trotted towards the aphid and used her antennae to drum on the part of the aphid abdomen, where she intended to lay the egg. Immediately she turned around and stuck her ovipositor into where she had attacked before. Sometimes her ovipositor was unsuccessful in penetration because the aphid was disturbed and moved away. In this case the parasite turned back and searched for its host again with her antennae. It was often found that the disturbed aphid carried the attacking parasite for a little while after the female parasite had inserted her ovipositor into its body. The parasite mostly laid her eggs in the abdomen of the aphid, rarely on the thorax or the head. Oviposition usually took 28 seconds.

Life cycle: Temperature was one of the important factors affecting the development of the *Aphelinus*. According to our experiments, the development of the immature stages at 23°C, from larva hatching to adult emergence usually took 11-12 days and 13-14 days respectively.

Adult food: The female *Aphelinus* required an adequate food supply to maintain egg production. In laboratory observations the adult could live as long as 24 days and usually 50% of the adults were still alive if honey and water were supplied regularly. Our experiment also showed that the adult needed food to produce mature eggs. If a newly emerged female was reared without any food, it would die within one or two days.

Newly emerged adults were fed on various food sources as honey water, raisin and water alone. They were placed in a glass tube 15 cm high and 6 cm diameter and prevented from escaping by a fine mesh cloth. The food source was placed on the inner wall of the container, and maintained at a room temperature of 24°C. The humidity was 70% and 10 hours a day given by 40 watt fluorescent lighting. The results obtained are shown in Table 9.

Table 9. Adult longevity of *Aphelinus* sp. influenced by different food

	Feeding honey & water (day)	Feeding raisin (day)	Feeding water (day)
Parasites	6.0	40	40.0
Shortest life	2.0	4	1.0
Longest life	24.0	11	6.0
Average (50% death)	15.5	10	4.5

Ephedrus (E.) persicae Froggatt (pl. 1, E)

E. (E.) persicae is a worldwide species. It may be easily distinguished from its allies by having deep fovea at the confluent point of the notaulus near the scutellar depression.

It has a rather wide host range in the world as Dr. Mackauer (1963) noted. Its host aphids are comprised of the species of *Dysaphis-Myzus-Rhopalosiphum* series. Stary and Schlinger noted that *E. (E.) persicae* was typically arboreal species usually associated with aphids in curled leaves of *Prunus* species in the Far East. Though *E. (E.) persicae* was recorded in various habitats, it was commonly seen to attack *Myzus persicae* in vegetable fields and citrus groves in Taiwan.

No male of *E. (E.) persicae* has ever been found so far. Our insectary rearing of *E. (E.) persicae* proved that it is an uniparental form in Taiwan. In January of 1970, we collected 170 aphid mummies which were parasitized by *E. (E.) persicae* on cabbage and reared them in a small container individually. The emerging parasites were all females. Thereafter we released the virgin females into a screen cage with a big colony of green peach aphids to allow free parasitization, their off-springs were also all females. This experiment showed that *E. (E.) persicae* is an uniparental form in Taiwan but its fecundity was as low as about 0.5% in our laboratory culture. We assummed that the low fecundity might be caused by the influence of the adult food supply.

Ephedrus (E.) plagiator (Nees) (pl. 1, A)

E. (E.) plagiator occurs in Europe and Far East. Since it has no distinct characteristics, it is not easily distinguished from its closely related species by using morphological description. However, it may be recognized by the following characters:

Body black; second radial abscissa of fore wing almost as long as first intercubitus; notaulus broad and rugose only at its base and effaced on disc; propodeum strongly carinated with pentagonal areola; first abdominal tergite 2-2.5 times as long as wide at spiracles, lateral longitudinal carinae present on basal 0.3-0.7 of the tergite; ovipositor sheath slender.

This parasite is polyphagous in all available habitats. When spring came the host aphids were omnipresent. They were commonly found on *Dactynotus, Macrosiphum, Sinomegoura* and *Acyrthosiphon* aphids, occasionally on *Myzus* and *Lipaphis* aphids on vegetable. Its population was usually low in the field except for dense populations of *E. (E.) plagiator* which were occasionally found on *Dactynotus formosanus.*

Diaeretiella rapae M'Intosh (pl. 1, F)

D. rapae is a worldwide species. It may be easily recognized by its greatly reduced fore wings, short radius and metacarpus; antenna 13 segmented in female and 16 segmented in male; propodeum weakly carinated with very narrow areola.

This parasite has a rather wide host range and mainly occurred in the vegetable fields of Taiwan. It was spread over the north and mountain areas of Taiwan but has never found in the south. *D. rapae* was encountered several times in the Taipei area in a low population but it soon died out. It was found to be commonly occurring in the mountain areas such as Lishan and Shengkuang from May to October. A record of *D. rapae* parasitizing *B. brassicae* colonies was made in September of 1968, and the number of mummies was found to be about 60% of the collected aphids.

Ephedrus (E.) robustus Liu (pl. 1, D)

This species is newly recorded in Taiwan. It is similar to *Ephedrus nacheri* of Japan (Takada, 1968). In the previous data this species was found in combination with *E. (E.) plagiator* (Nees). It differs from *Ephedrus (E.) plagiator* (Nees) by having a stout ovipositor sheath.

E. (E.) robustus was very common in attacking *Aphis spiraecola* during the months of the citrus flushing. A few of them were occasionally reared from mass colonies of *Longiunguis sacchari* in spring and autumn.

Lysiphlebia japonica (Ashmead) (pl. 1, B)

This species may be easily distinguished from its allies by the long metacarpus of the fore wing, short radius and short remained posterior cubitus.

L. japonica is a polyphagous species and widely distributed in the Far East. It was often abundant in various habitats in fields of rice, bean, corn, citrus and guava from October to May, and especially preferred to attack species of *Aphis*, *Longiunguis*, *Toxoptera* and *Rhopalosiphum*. These are major pests of field crops. Consequently, it could be considered as a valuable biological control agent of these species.

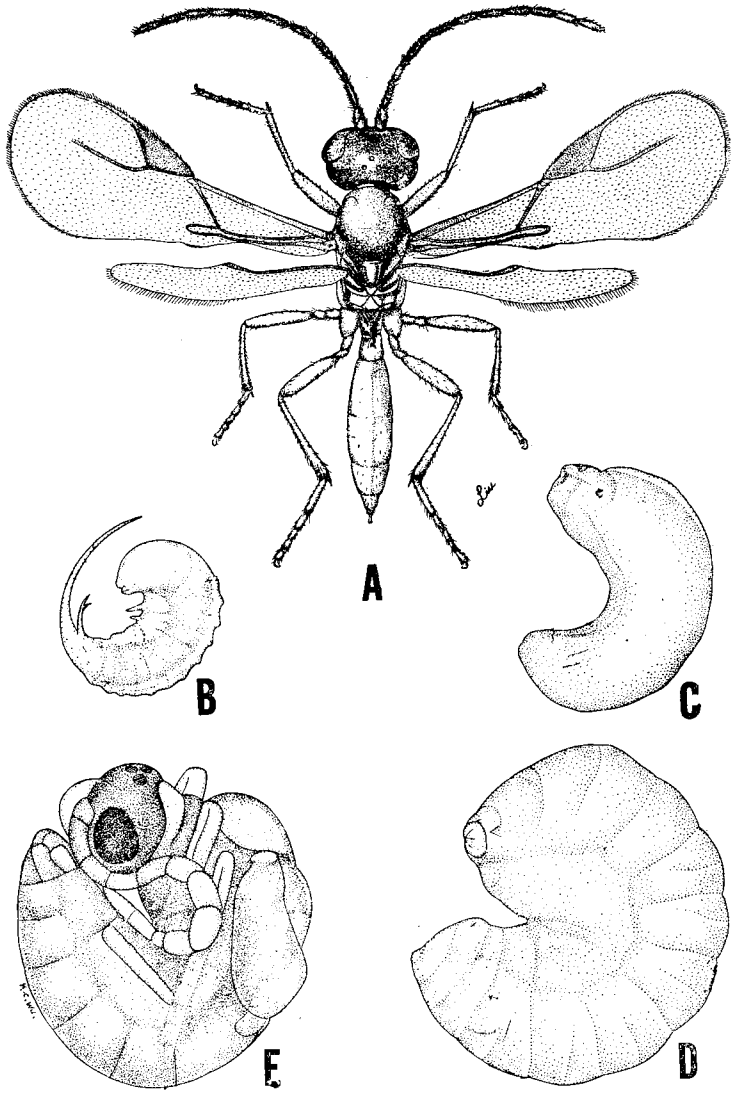


Fig. 6. *Lipolexis gracilis*: adult ♀ (A); 1st instar larva (B); 2nd instar larva (C); 3rd instar larva (D); pupa (E).

Lipolexis gracilis Forster (fig. 6, A-E)

This species may be recognized by its long radius and metacarpus of the fore wing, antenna 12-segments in female and 13-segments in male; first abdominal tergite with strongly developed central bifurcating carinae; ovipositor sheath slender and curved downwards and headed at apex.

It is a polyphagous species and widely distributed in Taiwan, India and Palearctic. It commonly occurs on garden, citrus, guava, melon and shrubbery, preferring to attack species of *Aphis*, *Toxoptera* and *Longiunguis* aphid during the months of October, December, March and April. We have never encountered the parasite in dense populations. According to our observations, it might be because of the size of the host which caused the parasite to prefer the first and second instars of the aphid as host.

VI. Studies on the mass production of green peach aphids and their parasites

Technique for breeding aphids

Radish and rape green were used as the host plants for rearing the peach aphid. The plants were growing in a 6- inch pot or in a 97×49×7 cm plastic tray with a mixture of compost and soil under green house condition. The 3-layer rack for putting pots or trays on is 1.25 m wide, 1.26 m long and 0.59 m deep. Four 40-w cool pink fluroescent tubes were hung on the top of each layer, as a light source providing 14 hour-photoperiod daily for plant growing.

About 20-25 days after seedling, the plant had already grown to the desired size. We moved the pot into the rearing room (22°-24°C, 60-70% R. H.) for aphid rearing 10 days later, so the aphid population on the plant would increase rapidly.

All observations of the aphid life cycle had been made in the rearing room as mentioned above. 5-7 days was required for a life cycle, thus, we considered that a 2- week rearing period would be the maximum for building up the predominantly old nymph (3rd to 4th instar) and adult population. It was also the longest period in which radish or rape green could maintain a large aphid colony successfully. The average number of offsprings per female for a generation is around 40 and the average length of aphid life was 22.6 days.

A comparison of using radish and rape green as aphid food plants was made by inoculating 40 aphids on the plants in the rearing room. The aphid population increased up to 217 after 7 days and 470 after 11 days on radish, 123 and 410 after the same duration on rape green respectively. It showed that radish was a little better than green rape for the aphid multiplication.

There were no sexual form of aphids produced in our rearing stock. Winged aphids were usually produced because of the heavy population or of the plant's maturation. In order to maintain a suitable population of aphids on the plants we had to change plants regularly to avoid the presence of wing formed aphids.

Rearing of the peach aphid parasite, *Aphidius gifuensis* Ashmead

Various attempts were made to maintain mass production of the pure culture of the parasite *Aphidius gifuensis* for exporting to the Introduced Beneficial Insects Investigation, Moorestown, New Jersey, U. S. A. There were many technical difficulties encountered, for instance, the host aphid multiplied too rapidly so that the host plants were seriously damaged within a short time, or the host aphids developed too slowly so that their colonies were too small and not suitable for parasite oviposition. The other problem was the difficulty in keeping the hyperparasites away from the green house where *Aphidius gifuensis* was being reared. The most influential hyperparasites such as *Charips* sp. (Cynipidae), *Aphidencyrtus aphidivorus* (Encyrtidae) and *Pachyneuron aphidis* (Pteromalidae) often attacked *Aphidius gifuensis* and greatly reduced its population.

Growing the host plants in an isolated room to prevent them from being attacked by other insects was also most important during our studies. In fact, the host plants were easily infested by flea beetle, diamond black moth, cabbage worm and leaf miner. Consequently, successful mass production of the parasite was dependant upon the proper combination of adequate host aphid, good parasites and healthy host plants.

The aphid population in each pot was maintained around 1,000 to 2,000 by brushing away the excess aphids daily. These pots were placed in the insectary to avoid fungus infestation induced by high moisture. Despite this the rearing room conditions for keeping healthy host plants and non-parasitized aphids growing needs improving. The following is a summary of rearing methods used in our laboratory.

The host plants, radish and rape green growing in pots, were inoculated with aphids in the room at 22°-24°C and 60-70% R. H. The mass production of non-parasitized aphids was continued until the instars III and IV of aphids appeared. Then, these non-parasitized aphids were removed into the screen cage for parasite inoculation.

The mummified aphids were obtained from the parasite stock which was maintained in a outdoor screened cage. They were then placed in a small glass vial (2×8 cm) covered with extra fine nylon cloth.

About 4 or 5 days later, the adult parasites emerged. They were immediately transferred into a larger glass vial (3.5×8 cm) supplied with 50% honey and water. The purpose of separation was to prevent the invading of early emerged hyperparasites. 35 to 50 *Aphidius gifuensis* females were collected daily and liberated into the fine mesh screen cage (30×35×30 cm), each cage containing one pot of rape green with 1,000 to 2,000 green peach aphids which were ready for parasite study. A few days later, numerous pale color, somewhat transparent and apparently bulky mummified aphids would appear.

VII. Shipment of parasites

During the fifth year of this project, the shipment of effective aphid parasites from Taiwan to the United States was a main part of our work. From January to April of 1970, a total of 2,039 aphid mummies including 933 *Aphidius gifuensis*, 572 *Trioxys communis*, 464 *Aphelinus* sp. and 70 *Ephedrus persicae* were shipped to Moorestown Parasite Introduction Laboratory using the following procedures.

Container: The shipping container, used for the transportation of mummified aphids, should be strongly constructed. A small transparent round-shaped plastic box about 4×1 cm in size and escape-proof was used for shipping the aphid parasite. This design of container is easily checked by the quarantine inspectors from the outside.

Packing: To prevent the container from damage en route, three pieces of 1.5 cm thick styrofoam (polylon) were used as wrapping material. The middle one had a hole of the same size as the plastic container, the other two pieces covered both sides, all of which was placed in an envelope and labelled with the address of receiver. The styrofoam (polylon) could protect the package from exposure to heat and cold during the shipping period. The cost, including packing and air mail express postage, is only one U.S. dollar from Taipei to Moorestown N. J., U.S.A.

Selection of parasitized aphid: When the mummified aphid began to change its color gradually from translucent to brown in *Aphidius* species, or black in *Aphelinus* and *Ephedrus* species, this was the best time for shipping, since the parasite has already reached the prepupal stage. From the beginning of aphid mummification to adult emergence takes about 5 to 7 days under insectary conditions (20°C). The period of larval and pupal stage was long enough for the parasite to travel from Taipei to Moorestown, N. J. by express air mail.

Supply of moisture and food to parasites: A piece of moistened cotton or sponge on to which a few drops of honey had been added was put into the container for the need of early emerging ones.

Part III: Aphid Predators

I. Aphid predators

Neuroptera: Hemerobiidae: *Eumicromus sauteri* Esben-Pets. Chrysopidae: *Chrysopa boninensis* Okam., *Chrysopa septempunctata* Wesm.

Coleoptera: Coccinellidae: *Propylaea japonica* Thunb.; *Coccinella repanda* Thunb., *Coccinella septempunctata bruckii* Muls.; *Coccinella octopunctata* Fabr., *Menochilus sexmaculatus* Fabr., *Coelophora chinensis* Weis., *Lemnia swinhoei* Crot., *Lemnia biplagiata* Swart, *Synonycha grandis* Thunb., *Leis dimidiata* Fabr., *Leis axyridis* Pall., *Platynaspidius maculosus* Weis., *Pseudaspidimerus japonensis* Nakane et Araki, *Scymnus (Pullus) hoffmanni* Weis., *Scymnus (Pullus) frontalis quadripustulatus* Herb., *Scymnus (Pullus)* sp.

Diptera: Chamaemyiidae: *Leucopis* sp. Syrphidae: *Paragus serratus* Fabr., *Paragus tibialis* Fail., *Melanostoma orientale* Wied., *Melanostoma univittatum* Wied., *Ischiodon scutellaris* Fabr., *Sphaerophoria formosana* Mats., *Paraxanthogramma nakamurae* Mats., *Asarcina aegrota* Fabr., *Metasyrphus confrater* Wied., *Metasyrphus corollae* Fabr., *Syrphus serrarius* Wied., *Syrphus vitripennis* Meig., *Epistrophe balteata* Dege., *Epistrophe horishana* Mats.

II. Identification of aphid predators

There are 3 species of neuropteroids, 16 species of coccinellids, 14 species of syrphids and 1 species of chamaemyiid feeding on citrus, vegetables and tobacco aphids in Taiwan. They may be identified by the following keys.

Key to aphidophagous neuropteroids

Adult

1. Brown color, small species, expanse 15-20 mm; fore wing with 3 or more apparent sectors, arising from R. .....Hemerobiidae

   Only one species of Hemerobiidae feeds on aphids in Taiwan i. e. *Eumicromus sauteri* Esben-Peterson. Syn. *Micromus sauteri* Esben-Peterson, *Micromus tumidius* Hag. (fig. 9, A).

   This is the only species of *Eumicromus* Nakhara known from this island, it is also distributed in South Japan and Ryukyu. This species can be distinguished from other known ones by the fore wings which are nearly uniform testaceous, closely reticulated with graybrown, and a short linear brown spot in the distal 1/2 of the narrow medio-cubital cell but without brownish gray fasciae; 7 or 8 branches to Rs. Tibiae of legs without markings.

   Green color, median size species, expanse 20-40 mm; fore wing with only a single sector from R near its base, costal cross-veins usually not forked in fore wing.....Chrysopidae

   There are 2 species feeding on aphids in Taiwan, they may be separated as bellows:

2. Comparatively small species, expanse 20-30 mm. In fore wing, cross-vein 1 from Rs to Psm touches Psm at apex of median loop, or beyond median loop. A black spot on each gena and a streak on each side of clypeus. (fig. 8, A) .....*Chrysopa boninensis*

   It also feeds on red mite and other soft bodied insects beside aphids.

   Comparatively larger species, expanse 35-40 mm. In fore wing, cross-vein 1 from Rs to Psm touches Psm before apex of median loop, 5-7 black spots, 2 just below antennae, 1 between antennae, 2 or 4 at side or side and base of labrum. (fig. 7, A) .....*Chrysopa septempunctata*

   Syn. *C. cognata* Mac Lachlan, *C. septempunctata cognata* Kuwayama, *C. pallens* Schneider, *C. nobilis* Brauer nec Heyden, *C. ricciana* Navas, *C. bipunctata* Burmeister, *Cintameva cognata* Navas, *C. bipunctata* var. *cognata*

Navas, *Hemerobius pallens* Rambur, *H. pallens* Rambur, *H. mauricianus* Rambur, *Nothochrysa robusta* Gerstaecker.

Egg

1. Egg elongate, oval-shaped, reddish brown, solitarily, without stalk, horizontally situated within aphid colonies. (fig. 9, B) ..... *Eumicromus sauteri*
   Egg elliptical, grayish green, with stalk, erected on leaf, twig or within aphid colonies, solitarily or close together..... 2
2. Egg stalk short, solitarily. (fig. 8, B)..... *Chrysopa boninensis*
   Egg stalk long, close together. (fig. 7, C-D) ..... *Chrysopa septempunctata*

Larva

1. Body naked, elongate, much longer than wide, about 1:5, without lateral tubercles and long setae; head without black markings, caudal segment elongate. (fig. 9, C)..... *Eumicromus sauteri*
   Body naked or covered with its host skin, broad, about 1:2 with lateral tubercles and long setae, head with black markings, caudal segment elongate, or triangular..... 2
2. Body large, part of dorsum covered with its host skin, head with 6 longitudinal and one short black streaks, caudal segment elongate. (fig. 8, C)..... ..... *Chrysopa boninensis*
   Body naked, head with 3 longitudinal black streaks, caudal segment triangular. (fig. 7, E) ..... *Chrysopa septempunctata*

Cocoon

1. Cocoon elongate, laced, very thin, pupa visible from outside. (fig. 9, D) .... *Eumicromus sauteri*
   Cocoon globular, thick, pupa concealed, not visible from outside..... 2
2. Cocoon comparatively smaller, 3×2 mm. (fig. 8, D) ..... *Chrysopa boninensis*
   Cocoon comparatively larger, 5×4 mm. (fig. 7, F) ..... *Chrysopa septempunctata*

Key to the adult of aphidophagous coccinellids of Taiwan

1. Body medium to large; about 3.5-13.0 mm in length; dorsum of body and compound eyes glabruous, without pubescence; metasternum with femoral lines not distinctly arcuate in extending to lateral sides. (pl. 2, A-K) 2
   Body small to medium; about 2.0-3.5 mm in length; dorsum of body and compound eyes pubescent; metasternum with femoral lines distinctly arcuate in extending to lateral sides. (pl. 2, L-P) 11
2. Humeral margin of elytra bordering pronotum nearly horizontal, not concave; elytral margination vague or slight and feeble before apical margin..... 3
   Humeral margin of elytra bordering pronotum concave or inclined backwards distinctly; elytral margination distinct 5
3. Body smaller; about 3.5-4.7 mm in length; prosternum with a pair of shorter mediastinal ridge extending only to the middle; elytra normally with 1

subtriangular subhumeral spot, 1 lateral rhomboidal postmedial spot each; black sutural margin with an antemedial transverse rectangular band and a shuttle-like postmedial spot respectively; these spots variable, sometimes simplified into 2 each or absent completely; pronotum with a distinct medial longitudinal longer ridge, reaching anterior 2/3; anterior margin of mesosternum with an obvious triangular concave in the medium. (fig. 13 A, pl. 5 E)

♀ Posterior margin of 5th abdominal sternum slightly curved or flat; of 6th rounded, sometimes with slightly convex apex at middle; pronotum with black marking convex anteriorly.

♂ Posterior margin of 5th abdominal sternum flat; of 6th nearly flat or emarginated at middle; pronotum: with black marking emarginated anteriorly. (pl. 3, J)

..... *Propylaea japonica*

Body larger; about 6-7 mm in length; prosternum with a pair of longer mediastinal ridge extending almost to the anterior margin 4

4. Elytra reddish yellow, with 3 transverse rows of black markings each: the basal 人-shaped, suboblique; medial stout band transverse sinuously on subapical 2/3, forming a cross with black sutural stripe; markings (based on margin) on apical 4/5 variable; anterior margin of mesosternum slightly convex in the medium (fig. 15, A)

♀ Posterior margin of 5th abdominal sternum flat; of 6th roundedly convex.

♂ Posterior margin of 5th abdominal sternum slightly concaved; of 6th truncate. (pl. 3, G)

..... *Coccinella repanda*

Elytra red or orange, with 7 rounded black spots; 2 laterally submarginal and 1 medial each, 1 common scutellar spot; these spots variable in shape, sometimes connected to each other; anterior margin of mesosternum horizontal. (fig. 14 A, pl. 4 C)

♀ Posterior margin of 5th abdominal sternum flat; of 6th pointedly rounded.

♂ Posterior margin of 5th abdominal sternum weakly arcuately concaved; of 6th truncate and with depressions at middle and basally with long hairs convering down. (pl. 3, H)

..... *Coccinella septempunctata bruckii*

Elytra orange to fulvous, normally with 4 transverse rows of black bands each: 1st band coalesced with 2 spots, oblique at basal 1/6, sometimes obsolete; 2nd band medially transverse from sutural stripe to submargin, sometimes interrupted in the middle; 3rd transverse band stout to postmedial 3/4, sometimes reduced into 1 spot; apical band rhomboidal at apex, sometimes obsolete body length 5.5-7.0 mm; posternum with 2 medial, longitudinal shorter ridge, feeble before the center; anterior margin of metasternum horizontal or curved backwards in the medium. (fig. 14 A, pl. 4 B)

♀ Posterior margin of 5th abdominal sternum convex at middle; of 6th pointed at middle.

♂ Posterior margin of 5th abdominal sternum slightly concaved; of 6th flat or emarginated at middle. (pl. 3, F)

..... *Coccinella octopunctata*

5. Antenna nearly as long as the width of frons; elytra red or reddish orange, sometimes elytra margin black, with 5 markings each; basal spot-shaped; medial band sinuous, across elytra transversely; apical spot normally suboval at 3/4. These spots variable, sometimes obsolate, reduced to simple spot or streak, or fused into large markings. (fig. 12 A, pl. 5 D)

♀ Posterior margin of 5th abdominal sternum flat; of 6th rounded or pointedly rounded.

♂ Posterior margin of 5th abdominal sternum flat or slightly concaved; of 6th truncate or emarginated at middle. (pl. 3, I)

..... *Menochilus sexmaculatus*

Antenna distinctly longer than the width of frons..... 6

6. Pronotum with ventral depression subhumeral..... 7

Pronotum without ventral depression subhumeral 9

7. Body smaller; 3.5-4.3 mm in length; frons with small protrusions downward laterally to basal clypeus; anterior margin of metasternum with slight concave in the medium; elytra black, with 3 rounded yellow spots each: 2 basal and 1 subapical. (fig. 20, A)

♀ Posterior margin of 5th abdominal sternum flat; of 6th gently rounded, exposed part small.

♂ Posterior margin of 5th abdominal sternum arcuately concaved distinctly; of 6th rounded, exposed part conspicuously. (pl. 3, K)

..... *Coelophora chinensis*

Body larger; 6.0-7.5 mm in length; frons with distinct protrusion downward laterally to basal clypeus; anterior margin of metasternum with large triangular concave in the medium..... 8

8. Anterior margin of medial area of pronotum black; elytra black, with 1 large subelliptical red or fulvous spot on the middle each, usually truncate submarginally. (fig. 10, A)

♀ Posterior margin of 5th abdominal sternum flat; of 6th truncate; labrum black.

♂ Posterior margin of 5th abdominal sternum weakly curved; of 6th weakly arcuately concaved; labrum white. (pl. 3, E)

..... *Lemnia swinhoei*

Anterior margin of medial area of pronotum with same color as that of the humeral spots which is normally fulvous; elytra red or reddish yellow, normally with 1 rounded black basal spot each, a black transverse subapical band reaching either subapical margin forming an anchor-like marking with black sutural stripe; these elytra markings sometimes absent or variable. (fig. 11 A, pl. 4 A)

♀ Posterior margin of 5th abdominal sternum flat; of 6th truncate

or gently rounded; labrum black.

♂ Posterior margin of 5th abdominal sternum weakly concaved; of 6th emarginated or truncate and with a row of hair on it; labrum white. (pl. 3, D)

..... *Lemnia biplagiata*

9. Tarsal claws bifid at end, without basal tooth; fairly large beetle, body 11.0-13.0 mm in length; elytra with 6 black spots each and a large scutellar spot, arranged as follows: 1 basally, 2 medial, 2 postmedial, 1 on suture. (fig. 19, A)

♀ Posterior margin of 5th abdominal sternum weakly convex resulting in the 6th one exposed slightly or hidden; of 6th convex.

♂ Posterior margin of 5th abdominal sternum flat; of 6th truncate or emarginated at middle, exposed mostly. (pl. 3, A)

..... *Synonycha grandis*

Tarsal claws not bifid at end, with tooth at base; body about 5.4-10.0 mm in length 10

10. Body rounded; 7.0-10.0 mm in length; elytra yellowish-orange to reddish-orange, 1 black spot on suture subapical, and 6 on each: 1 basal, 3 medial, 2 postmedial. (fig. 17, A)

♀ Posterior margin of 5th abdominal sternum slightly convex at middle; of 6th gently rounded or convex at middle.

♂ Posterior margin of 5th abdominal sternum weakly arcuately concaved; of 6th emarginated at middle and hairy on the depressed margin. (pl. 3, B)

..... *Leis dimidiata*

Body oval; 5.4-8.0 mm in length; 3.8-5.2 mm in width; elytra black, with a red round spot on the middle of each, sometimes with 2 such spots each: 1 larger antemedial, 1 smaller posterior; elytral coloration similar to that of *Lemnia swinhoei*, except the red round spots somewhat smaller and never truncated in outer lateral side, and with variation of coloration as mentioned. (fig. 18, A)

♀ Posterior margin of abdominal sternum convex at middle; of 6th rounded; labrum black.

♂ Posterior margin of abdominal sternum weakly arcuately concaved; of 6th roundedly concaved; labrum white. (pl. 3, C)

..... *Leis axyridis*

11. Clypeus laterally extending across frontal side of compound eyes; base of antenna completely covered by clypeus; dorsum of body hairy; elytra with 5 spots: 1 on sutural stripe postscutellarly, 1 on anterior 1/2 and 1 on posterior 1/2 each. (fig. 22, A)

♀ Posterior margin of abdominal sternum flat; of 6th rounded and with a convex apex at middle.

♂ Posterior margin of abdominal sternum weakly arcuately concaved; of 6th gently rounded. (pl. 3, L)

..... *Platynaspidius maculosus*

Clypeus not laterally extending, if so, base of antenna exposed 12
12. Coxal areas surrounded by metasternal femoral lines depressed 13
Coxal areas surrounded by metasternal femoral lines normal, not depressed...14
13. Elytra black, with 1 discoidal red or reddish-orange postmedial spot each, body 2.0-2.5 mm in length. (fig. 21, A)
♀ Posterior margin of abdominal sternum flat; of 6th roundedly convex.
♂ Posterior margin of abdominal sternum weakly arcuately concaved; of 6th rounded. (pl. 3, M)
..... *Pseudaspidimerus japonensis*
Elytra black, with a red or reddish yellow elongate band from sub-basal to post medial each, the apical end of the band always broader than the basal; body 2.0-3.0 mm in length. (fig. 24, A)
♀ Posterior margin of abdominal sternum flat or slightly concaved; of 6th rounded.
♂ Posterior margin of abdominal sternum slightly concaved; of 6th gently rounded. (pl. 3, O)
..... *Scymnus (Pullus) hoffmanni*
14. Elytra black, with 4 red suboval spots: 1 obliquely submedial and 1 subrectangular at posterior 2/3 each; body 1.6-2.1 mm in length (fig. 23, A).
♀ Posterior margin of abdominal sternum roundedly concave; of 6th emarginated at middle.
♂ Posterior margin of abdominal sternum weakly arcuately concaved; of 6th rounded. (pl. 3, N)
.....*Scymnus (Pullus) frontalis quadripustulatus*
Elytra black, immaculate; apical part of elytra and abdomen fulvous. (fig. 25, A); body 1.6-2.2 mm in length.
♀ Posterior margin of abdominal sternum flat; of 6th arcuately concaved.
♂ Posterior margin of abdominal sternum flat; of 6th arcuately concaved. (pl. 3, P)
..... *Scymnus (Pullus)* sp.

In some species of coccinellids the coloration of markings are variable, but then can be identified by the genitalia. Thus a key to species based on male and female genitalia is necessary and is given below.

KEY TO THE ADULT OF APHIDOPHAGOUS COCCINELLIDS OF TAIWAN

(based on male genitalia, pl. 6)

1. Sipho with a membranous lapel-like appendix at apical one-fourth. (pl. 6, L)
..... *Platynaspidius maculosus*
Sipho without such appendix 2
2. Length of tegmen (exclusive of process of basal piece and median strut): 0.68-1.68 mm..... 3

Length of tegmen (exclusive of process of basal piece and median strut): 0.32-0.48 mm.....13

3. Sipho relatively slender, 3-4 times as long as siphonal capsule (length of outer process plus that of inner process) 4

Sipho relatively slender, about 4.5-7.5 times as long as siphonal capsule..... 9

4. Ventral aspect of sipho without variation at subapical part 5

Ventral aspect of sipho with a short slender part extended reversely along it 8

5. Lateral lobes relatively short and nearly as long as basal piece, ventral aspect of apex with claw-like part; basal piece broader than its length..... 6

Lateral lobes relatively long and distinctly longer than basal piece, ventral aspect of apex without claw-like part; basal piece longer than its width. 7

6. Sipho with membranous appendage irregular in form instead of tapering off; median piece of tegmen laterally pointed slightly on both lateral side of apex, in triangular shape for the most part. (pl. 6, A) .....*Synonycha grandis*

Sipho tapering off apically; median piece of tegmen narrowed distinctly at subapical part, elongate ellipse shaped for the most part except the apical part like the head of Dugesia. (pl. 6, F) .....*Coccinella octopunctata*

7. Tegmen relatively slender; lateral aspect of the lateral lobes with broadened ends basally and apically; ventral aspect of median piece elongate and tapering apically, and laterally pointed slightly on both lateral sides of apex; upper margin of basal piece without distinct depression dorsally. (pl. 6, C).....*Leis axyridis*

Tegmen relatively stout; lateral aspect of the lateral lobes with narrowed part locally at middle; ventral aspect of median piece ellipse shaped except apical part which contracts suddenly like a short handle; upper margin of basal piece with a large depression dorsally. (pl. 6, B) .... *Leis dimidiata*

8. Lateral lobes with setae longer than the width of the base; median piece much longer than lateral lobes; median piece with both lateral sides distinctly folding back ventrally and forming an opening at apex. (pl. 6, H) ..... *Coccinella septempunctata bruckii*

Lateral lobes with setae as long as the width of the base; median piece with both lateral sides indistinctly folded back ventrally; median piece slightly longer than lateral lobes. (pl. 6, G).....*Coccinella repanda*

9. Siphonal apical appendage leaf-shaped, the connection between sipho and its appendage like human articulus knee; sipho with a distinct convex part ventrally, near the central section 10

Siphonal apical appendage tapering off or slender band shaped; sipho without distinct convex part ventrally.....11

10. Median piece relatively slender, apical part especially narrow. (pl. 6, E)..... ..... *Lemnia swinhoei*

Median piece relatively broader, tapering from base without especially narrowed apical part. (pl. 6, D).....*Lemnia biplagiata*

11. Median piece greatly varied into "H" shape; lateral lobes stout. (pl. 6, K)..... ..... *Coelophora chinensis*
    Median piece normally in elongate leaf shape; lateral lobes slender.....12
12. Lateral lobes with short setae sparsely, setae not longer than the width of subapical lateral lobe; tegmen about 0.95 mm in length (exclusive of median strut). (pl. 6, I) .....*Menochilus sexmaculatus*
    Lateral lobes with long setae thickly, setae 1.5-2.0 times as long as the width of subapical lateral lobe; tegmen about 0.74 mm in length. (pl. 6, J) ....*Propylaea japonica*
13. Median piece with variation apically, both lateral sides folded back ventrally except apical part forming two laterally pointed sides. (pl. 6, N) .... *Scymnus (Pullus) frontalis quadripustulatus*
    Median piece without such variation ventrally.....14
14. Lateral lobes stout and with relatively long setae thickly along the outer margin except the basal part, surface of lateral lobes with some short setae; median piece shorter than lateral lobes. (pl. 6, P)...*Scymnus (Pullus)* sp.
    Lateral lobes slender with relatively short setae sparsely at apex; median piece longer than lateral lobes 15
15. Siphonal capsule with longer outer process than inner process. (pl. 6, O) .... *Scymnus (Pullus) hoffmanni*
    Siphonal capsule with shorter outer process than inner process. (pl. 6, M)..... ..... *Pseudaspidimerus japonensis*

KEY TO THE ADULT OF APHIDOPHAGOUS COCCINELLIDS OF TAIWAN

(based on female genitalia, pl. 7)

1. Receptaculum seminis with distinct part of ranus..... 2
   Receptaculum seminis without distinct part of ranus 9
2. Ranus with rather distinct nodulus; apical and subapical area of hemisternits with thick and strong setae. (pl. 7, L) ..... *Platynaspidius maculosus*
   Ranus without nodulus or with indistinct nodulus; apical margin of hemisternits with sparse state 3
3. Receptaculum seminis slender, parallel-sided and rather strongly arcuate. (pl. 7, A)..... *Synonycha grandis*
   Receptaculum seminis with irregular form 4
4. Ranus located laterally at the middle of receptaculum seminis. (pl. 7, K) .... *Coelophora chinensis*
   Ranus located at the base of receptaculum seminis. 5
5. Infundibulum indistinct or not sclerotized; hemisternits with narrowed apical part, outerside of basal handle biparted. 6
   Infundibulum large and well-sclerotized; hemisternits with apical part relatively broad..... 7
6. Stylus with 2 long setae. (pl. 7, C) .....*Leis axyridis*
   Stylus with a tuft of setae. (pl. 7, B) ..... *Leis dimidiata*
7. Inner side of basal cornus without protuberant part. (pl. 7, F) .....

..... *Coccinella octopunctata*

Inner side of basal cornus with protuberant part 8

8. Protuberant part of basal cornus longer than ranus. (pl. 7, G) .....
..... *Coccinella repanda*

Protuberant part of basal cornus shorter than ranus. (pl. 7, H) .....
..... *Coccinella septempunctata bruckii*

9. Hemisternits with a wrenched base in round fan shape 10

Hemisternits with base not in round fan shape 11

10. Base of receptaculum seminis with a relatively expanded inner side forming a distinct concave shape to the sub-basal inner side. (pl. 7, E) .....
..... *Lemnia swinhoei*

Base of receptaculum seminis with a slightly expanded inner side without distinct concave shape mentioned above. (pl. 7, D) .....*Lemnia biplagiata*

11. Hemisternits larger, 0.42-0.55 mm in length 12

Hemisternits smaller, 0.15-0.36 mm in length 13

12. Hemisternits wrenched outward; stylus with 2 setae. (pl. 7, J) .....
..... *Propylaea japonica*

Hemisternits not wrenched basally; stylus with 3 setae. (pl. 7, I) .....
..... *Menochilus sexmaculatus*

13. Hemisternits with thick and strong setae on the area of one-fourth apically; receptaculum weakly arcuate like the bottle-goured with narrowed base and expanded apically with round tip. (pl. 7, M)...*Pseudaspidimerus japonensis*

Hemisternits provided with setae or bearing small pores except the basal area; receptaculum seminis narrowed at middle or not sclerotized. 14

14. Receptaculum seminis not sclerotized; hemisternits with relatively long setae apically, surface of the plate sparsely bearing small pores. (pl. 7, N) .....
..... *Scymnus (Pullus) frontalis quadripustulatus*

Receptaculum seminis sclerotized; hemisternits with short setae except the basal area.....15

15. Receptaculum seminis with appendix at tip; stylus with a short seta, 1-2 times as long as stylus. (pl. 7, O) .....*Scymnus (Pullus) hoffmanni*

Receptaculum seminis with appendix at tip; stylus with long setae, 3 times longer than stylus. (pl. 7, P) ..... *Scymnus (Pullus)* sp.

Eggs of coccinellids are difficult to identify, the following key is only to separate the main groups. The separation of eggs of relative species under the main groups depends on the size and proportion of length and width.

KEY TO THE EGG OF APHIDOPHAGOUS COCCINELLIDS OF TAIWAN (illustration 3)

1. Eggs laid horizontally in variable direction 2

Eggs laid vertically 5

2. Eggs fusiform or elongate ellipsoidal 3

Eggs in different forms 4

3. Eggs yellow, length 0.6 mm, width 0.35 mm, ratio 1.71:1. (fig. 26, N) .....
..... *Scymnus (Pullus) hoffmanni*

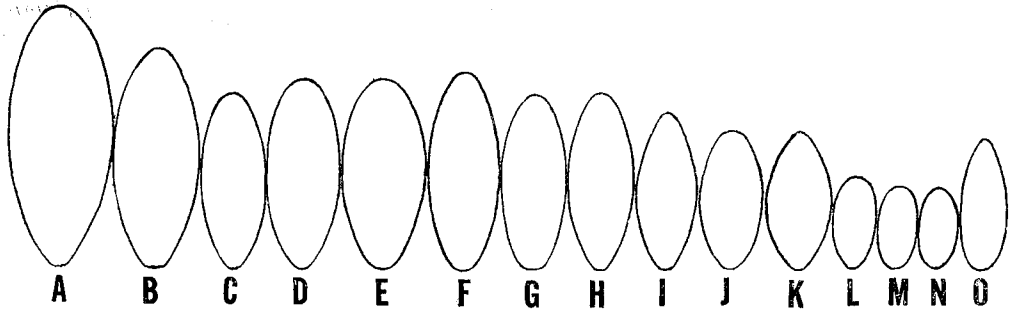


Illustration 3: Egg of coccinellids: *Synonycha grandis* (A); *Leis dimidiata* (B); *Leis axyridis* (C); *Lemnia biplagiata* (D); *Lemnia swinhoei* (E); *Coccinella octopunctata* (F); *Coccinella repanda* (G); *Coccinella septempuncata bruckii* (H); *Menochilus sexmaculatus* (I); *Propylaea japonica* (J); *Coelophora chinensis* (K); *Pseudaspidimerus japonensis* (L); *Scymnus* (*Pullus*) *frontalis quadripustulatus* (M); *Scymnus* (*Pullus*) *hoffmanni* (N); *Scymnus* (*Pullus*) sp. (O).

Eggs yellow, length 0.5-0.6 mm, width 0.3-0.35 mm, ratio 1.67:1-1.71:1. (fig. 26, M).....*Scymnus* (*Pullus*) *frontalis quadripustulatus*

Eggs greenish, length 0.65 mm, width 0.40 mm, ratio 1.63:1 (fig. 26, L) .....*Pseudaspidimerus japonensis*

4. Length 1.0 mm, width 0.30 mm, ratio 3.33:1. .....*Platynaspidius maculosus*

Length 1.0-1.2 mm, width 0.40-0.45 mm, ratio 2.50:1-2.67:1 (fig. 26, O) ..... *Scymnus* (*Pullus*) sp.

5. Length 1.09-1.20 mm, width 0.51-0.53 mm, ratio 2.14:1-2.26:1 (fig. 26, E) ..... *Lemnia swinhoei*

Length 1.37-1.53 mm, width 0.54-0.58 mm, ratio 2.54:1-2.56:1. (fig. 26, D)..... *Lemnia biplagiata*

Length 1.10-1.36 mm, width 0.45-0.56 mm, ratio 2.44:1-2.43:1. (fig. 26, H)..... *Coccinella septempunctata bruckii*

Length 1.35-1.61 mm, width 0.45-0.65 mm, ratio 2.44:1-2.43:1. (fig. 26, F) ..... *Coccinella octopunctata*

Length 1.09-1.20 mm, width 0.51-0.53 mm, ratio 2.14:1-2.26:1. (fig. 26, G)..... *Coccinella repanda*

Length 1.09-1.21 mm, width 0.51-0.56 mm, ratio 2.14:1-2.16:1. (fig. 26, C)..... *Leis axyridis*

Length 1.5 mm, width 0.65 mm, ratio 2.31:1. (fig. 26. B) .....*Leis dimidiata*

Length 1.68-1.86 mm, width 0.78-0.87 mm, ratio 2.15:1-2.14:1 (fig. 26, A) ..... *Synonycha grandis*

Length 0.90-1.10 mm, width 0.40-0.52 mm, ratio 2.51:1-2.12:1 (fig. 26, J) ..... *Propylaea japonica*

Length 1.10 mm, width 0.50 mm, ratio 2.20:1 (fig. 26. I).....*Menochilus sexmaculatus*

Length 0.93-1.01 mm, width 0.47-0.53 mm, ratio 1.98:1-1.91:1. (fig. 26, K) ..... *Coelophora chinensis*

KEY TO THE LARVA OF APHIDOPHAGOUS COCCINELLIDS OF TAIWAN

1. Body fusifrom, large or medium-size, dorsum with distinct tubercles but without white waxy secretion, legs long, most parts of legs visible in walking 2
   Body ovate, small-size, dorsum with indistinct tubercles and white waxy secretion; if body fusiform, legs short, invisible or partly visible in walking 12
2. Dorsum of 1st abdominal segment with tubercles unicoloured, orange; tubercles of 2nd and 3rd abdominal segments not unicoloured but consisting of both orange and black ones, dorsal and dorso-lateral tubercles in "Long type" (tubercles about 2 times or more as long as its width at middle) 3
   Dorsum of 1st abdominal segment with blackish dorsal tubercles, dorso-lateral and lateral ones orange; tubercles of 2nd & 3rd abdominal segments unicoloured black 6
3. Meso- and metathorax and 4th abdominal segment with orange red or whitish yellow tubercles; dorso-lateral tubercles not distinctly split 4
   Meso- and metathorax with black tubercles; dorso-lateral tubercles of 4th abdominal segment orange, lateral ones black; dorsal and dorso-lateral tubercles distinctly split. (pl. 8, B-C) 5
4. Tubercles in "Scolus type" (with multi-denticulate chalaza as its branches, similar in size, chalaza with apical seta 3 times as long as the basal part of chalaza) (pl. 8, I); body median-size; tubercles of meso- metathorax, and lateral ones of 1st to 8th abdominal segments orange-red or white. (fig. 12, C) ..... *Menochilus sexmaculatus*
   Tubercles in "Sentus type" (elongate conical, without branches, with setae scattered heavily on them) (pl. 8, A); body large, lateral tubercles of 1st, 2nd, and 4th abdominal segments yellowish-white or white, except those mentioned, other lateral ones black. (fig. 19, C) ..... *Synonycha grandis*
5. Tubercles of 5th abdominal segment unicoloured, black. (pl. 8 B, fig. 17 C) ..... *Leis dimidiata*
   Dorsal and dorso-lateral tubercles of 5th abdominal segment orange red, lateral ones black. (pl. 8 C, fig. 18 C) ..... *Leis axyridis*
6. Dorsal tubercles of 5th to 9th abdominal segment black 7
   Dorsal tubercles of 5th to 9th abominal segment besides black with light orange ones 9
7. Ground colour of dorsal thorax and tubercles black; abdominal tubercles in "Struma type" (warts with some short chalaza including a short seta on it), apex of dorsal and dorso-lateral tubercles with 2 main chalaza; apex of lateral ones with only 1 chalaza. (pl. 8 F, fig. 16 C) ..... *Coccinella octopunctata*
   Ground colour of thoracic dorsum and tubercles involving black and orange red; abdominal tubercles in "Parascolus type" (tubercles rather distinct with chalaza branched) 8

8. Both anterior and posterior prothorax with distinct red markings; meso- and metathorax including tubercles entirely black; dorsal tubercles of 4th abdominal segment black; abdominal tubercles with many distinct chalaza including a strong seta 2.5-6 times as long as chalaza. (pl. 8 H, fig. 14 C).....*Coccinella septempunctata bruckii*

Prothorax with 2 reddish orange markings anteriorly, meso- and metathorax with reddish orange markings mediastinally; tubercles of metathorax reddish; dorsal tubercles of 4th abdominal segment reddish orange, abdominal tubercles with lesser chalaza and a distinct seta on it. (pl. 8 G, fig. 15 C).....*Coccinella repanda*

9. Posterior margin of 7th dorsal abdominal segment reddish orange; dorsal and dorso-lateral tubercles of abdomen in "Long type" (defined as before but shorter than that of *Menochilus sexmaculatus*) chalaza with an apical seta, 1.5-5 times as long as the basal part of chalaza.....10

Ground colour of 7th abdominal segment black, abdominal tubercles in "Parascolus type" or in "Struma type" 11

10. Ground colour and tubercles of 4th abdominal segment reddish orange, lateral tubercle of 6th and 7th abdominal segment black. (pl. 8 E, fig. 10 C) ..... *Lemnia swinhoei*

Dorsal and lateral tubercles of 4th abdomen reddish orange; dorso-lateral ones black; lateral tubercles of 6th and 7th abdominal segment reddish. (pl. 8 D, fig. 11 C)..... *Lemnia biplagiata*

11. Meso- and meta-thorax with "I"-shaped markings mediastinally; lateral tubercles of 1st to 7th abdominal segment with whitish lateral tubercles also; dorsum of 1st to 7th abdominal segment with whitish median area; dorsal and dorso-lateral tubercles of abdominal segment in "Parascolus type" with some chalaza including a short apical seta, 1-1.5 time as long as the basal part of chalaza. (pl. 8 J, fig. 13 C) .....*Propylaea japonica*

Meso- and meta-thorax with large yellowish white marking nearly rounded, lateral-anterior margin of mesothorax with yellowish-white markings; all lateral tubercles of abdominal segment black except yellowish-white 1st and 4th ones; dorsal median area and dorsal tubercles of 4th to 7th abdominal segments yellowish-white; abdominal tubercles in "Struma type" (with one large chalaza at tip and some smaller ones with a rather long slender apical seta which is about 10 times or more as long as the basal part of the chalaza. (pl. 8 K, fig. 20 C).....*Coelophora chinensis*

12. Body ovaliform, not covered with white waxy secretion; legs very short and invisible in walking 13

Body fusiform, covered with white waxy secretion; legs short but visible in walking 14

13. Dorsum of prothorax with 2 blackish square markings, antennae long; spiracles indistinct; tubercles in "Chalaza type" (small chalaza with a short and slender seta). (fig. 22, B) .....*Platynaspidius maculosus*

Dorsum of prothorax without markings; antennae short, spiracles distinct, tubercles in "Chalaza type" but indistinct; chalaza with a long slender

seta. (pl. 8 Z, fig. 21 C) ..... *Pseudaspidimerus japonensis*

14. Body with dense white waxy, rod-like secretion..... 15
    Body with white waxy cottony secretion; abdominal tubercles in "Struma type" with some chalaza similar in size, including apical one with a long slender apical seta which is 3-5 times as long as the basal part of chalaza. (pl. 8 M, fig. 24 C)..... *Scymnus (Pullus) hoffmanni*
15. Each segment with 6 short rod-like and straight upward waxy secretion; tubercles in "Chalaza type" with fine chalaza seta which is long and slender, 5-6 times as long as the basal part of chalaza. (pl. 8 L, fig. 23 C)..... *Scymnus (Pullus) frontalis quadripustulatus*
    Each segment with 6 rod-like waxy secretion, long and curved; in addition prothorax with 4 more behind it, tubercles in "Struma type" each one with a small wart including 2 chalaza with a long slender apical seta about 2-3 times as long as the basal part of chalaza; the apical chalaza is larger than the other. (pl. 8 N, fig. 25 C)..... *Scymnus (Pullus)* sp.

KEY TO THE PUPA OF APHIDOPHAGOUS COCCINELLIDS OF TAIWAN (plate 9)

1. Body with markings 2
   Body immaculate 12
2. 1st abdominal segment with markings 3
   1st abdominal segment immaculate 6
3. Body relatively small, 3.5-4.0 mm in length, with short fine heavy setae; metathorax brownish black except median area with a large orange square. (pl. 9 K, fig. 20 D) ..... *Coelophora chinensis*
   Body relatively large, 5.0-6.5 mm in length, with short fine rather sparse setae; metathorax without median orange square as mentioned above..... 4
4. 1st abdominal segment divided into 3 subequal parts by 2 distinct suboval markings; middle part of elytra bud with 2 black suboval markings, 2 lateral ones smaller and contiguous to the black end parts of elytra bud. (pl. 9 H, fig. 14 D) ..... *Coccinella septempunctata bruckii*
   1st abdominal segment with 2 irregular faint markings not dividing the segment into 3 subequal parts as *Coccinella septempunctata;* middle part of elytra bud with 2 suboval markings, tail like, on inner sides, or like two hands holding something; without lateral markings except the extended black end..... 5
5. Metathorax and 1st abdominal segment blackish brown except the central area and the lateral parts of 1st abdominal segment; in dorsal view of body, elytra bud with end marking dilated like a band along the margin. (pl. 9 F, fig. 16 D) ..... *Coccinella octopunctata*
   Metathorax blackish brown except central area; 1st abdominal segment brownish yellow with 2 small feeble brownish markings; in dorsal view of body, elytra bud with end marking dilated broadly not like a band. (pl. 9 G, fig. 15 D) ..... *Coccinella repanda*
6. Lateral process of 3rd, 4th and 5th abdominal segments with a lateral horn,

which is longer than the width of lateral process; body large, length 9.0-11.0 mm. (pl. 9 A, fig. 19 D) ..... *Synonycha grandis*

Lateral process of abdominal segments without horn; body median-sized, length 3.0-8.0 mm. 7

7. 2nd abominal segment without markings, if present, extending like a small black part from the markings of 3rd abdominal segment to its posterior margin; elytra bud without markings in median area, with 2 black suboval lateral markings; metathorax and posterior area of prothorax with 2 black suboval markings respectively 8

2nd abdominal segment with single markings or a large marking extending from 3rd abdominal segment; middle part of elytra bud with faint marking, if not, lateral markings without suboval ones 9

8. Prothorax with only 2 suboval posterior markings; markings of 3rd abdominal segment enlarged and a small part extending to 2nd abdominal segment. (pl. 9 D, fig. 11 D)..... *Lemnia biplagiata*

Prothorax with 4 black suboval markings: 2 anterior smaller, 2 posterior larger; 2nd abdominal segment immaculate. (pl. 9 E, fig. 10 D) .... *Lemnia swinhoei*

9. Ground colour of pupa bright orange, all markings black explicitly; elytra bud with a suboval lateral marking..... 10

Ground colour of pupa fulvous or mixed with orange, all markings blackish brown obscurely; elytra bud with markings but never suboval in shape...11

10. 4th abdominal segment with distinct large markings; body relatively smaller, length 5.0-5.5 mm. (pl. 9 C, fig. 18 D) ..... *Leis axyridis*

4th abdominal segment with markings or with small spots; body relatively larger, length 7.0-8.0 mm. (pl. 9 B, fig. 17 D) ..... *Leis dimidiata*

11. Middle area of elytra bud without markings; posterior margins of prothorax and metathorax with 2 suboval markings each. (pl. 9 J, fig. 13 D) .... *Propylaea japonica*

Middle area of elytra bud with 2 curved band-like markings from posterior to anterior; markings transversely along posterior margin of prothorax, irregular in shape; metathorax with variable and complicated markings instead of simple suboval ones as mentioned above. (pl. 9 I, fig. 12 D) ..... *Menochilus sexmaculatus*

12. Body without whitish waxy secretion.....13

Body with whitish waxy secretion 14

13. Body brownish black, about 3.0 mm in length, with heavy scattering distinct, short fine setae. (pl. 9 L, fig. 22 C) ..... *Platynaspidius maculosus*

Body reddish brown, about 2.5 mm in length, without distinct fine setae (pl. 9 M, fig. 21 D)..... *Pseudaspidimerus japonensis*

14. Body fusiform, prothorax with 8 distinct small processes along anterior and lateral markings; each abdominal segment with small distinct processes and a short stout apical seta on each process. (pl. 9 C, fig. 25 D) .... *Symnus (Pullus)* sp.

Body suboval; prothorax and abdominal segments without distinct processes

as mentioned above. (pl. 9 N, fig. 24 D, 23 D).....
.....*Scymnus (Pullus) hoffmanni* and *Scymnus (Pullus) frontalis quadripustulatus.*

KEY TO ADULT OF APHIDOPHAGOUS CHAMAEMYIID AND SYRPHIDS OF TAIWAN

1. Usually densely gray-pruinose species, the oval abdomen usually pictured with paired brown spots.....Chamaemyiidae
   Only one species feeds on aphids on this islands i. e. *Leucopis* sp. (fig. 27 A)
   Characteristically flower flies with yellow abdomen present black markings, quick flies and good hoverers .....Syrphidae

There are 14 species feeding on aphids and may be separated as in the following key:

KEY TO ADULT OF APHIDOPHAGOUS SYRPHIDS OF TAIWAN

1. Small sized, body 4.5-6.0 mm long; mouth opening narrow, not hollowed; abdomen sub-oval and distinctly convex 2
   Small or medium sized, body 6-14 mm long; mouth opening sub-oval, or and hollowed basally; abdomen more or less slender 3
2. Scutellum sub-rectangular and black, width 2-2.5 times as long as length, hind margin broadly yellow and with serrated edge of about 13-16 teeth; thorax shining black with a pair of greyish median stripes, which united broadly in the center of anterior portion, lateral side of thorax shining black, mesopleura to sternopleura conspicuously pubescent, greyish-white and long; occipital margin or behind the orbits with long brownish pubescence; abdomen sub-oval, nearly as long as the length from frons to scutellum; 1st segment black; 2nd yellowish brown and black laterally, hind medial margin with a small or transverse variable brownish black marking; 3rd and 4th with arched transverse brownish black bands; apex brownish black; body stout, length 4.5-5.5 mm. (pl. 10, A)..... ..... *Paragus serratus*
   Scutellum semi-rounded, black or brownish black, hind margin arcuate, without serrated edge; thorax shining black without marking; mesopleura with short brownish pubescence; occipital margin or behind the orbits with short brownish pubescence; abdomen fusiform: 1st and 2nd segments black, 3rd brown, 4th brownish-black, 5th blackish-brown, sometimes brownish-black entirely; body comparatively slender, length 5-6 mm. (pl. 10, B).....*Paragus tibialis*
3. Face and scutellum entirely black..... 4
   Face at least partly yellowish..... 5
4. Face in profile with a distinct small central bump; thorax shining black; abdomen orange-yellow: 1st segment black, hind margin of 2nd-4th with a black transverse band in ♂, which in the ♀ is widened up to about lateral median margin, 5th segment except the front margin black; a

distinct median stripe on 2nd-4th segments black, body length about 6.5 mm. (pl. 10, C) ..... *Melanostoma orientale*

Face in profile without distinct central bump, being nearly straight above and below this point; thorax shining brownish black; abdomen orange: 1st segment black, 2nd, 3rd and 4th segments with a narrow black hind margin in ♂, which in ♀ widened and extended at sides up to about the middle of lateral margin; a narrow median black stripe on 2nd-3rd segments of ♂, also on 4th of ♀ sometimes indistinct; hind margin of 5th with an indefinite brown marking; male genitalia large, body length about 6.5 mm. (pl. 10, D) ..... *Melanostoma univittatum*

5. Thorax with conspicuous yellow lateral lines; pleurae also with yellow markings 6

Thorax without conspicuous yellow lateral line and pleural marking 8

6. Abdomen comparatively broader, usually wider than thorax; in male under side of hind trochanters with a distinct process; 3rd joint of antennae large, about 2 times longer than 1st and 2nd united; abdomen yellowish: 1st segment black except the lateral, 2nd with brownish black transverse "H" shape marking, 3rd and 4th with a brownish black band posteriorly, each band extending to lateral sides, slightly arcuated in middle; body length 9-10 mm. (pl. 10, E) ..... *Ischiodon scutellaris*

Abdomen broad or narrow; hind trochanters smooth; 3rd joint of antennae as broad as long 7

7. Body smaller, length 6.0-7.0 mm; thorax shining aeneus black, with a pair of inconspicuous greyish median stripes at least on anterior portion; scutellum yellowish with yellowish pubescence; abdomen yellow or yellow-orange, narrower than thorax and almost parallel side: 1st segment black, except the lateral, front and hind margins of 2nd-5th segments with a black band extending to sides, median hind margin of 5th segment with variable marking, sometimes indistinct. (pl. 10, F) .... *Sphaerophoria formosana*

Body larger, length about 9.0 mm; thorax shining black; scutellum yellowish, with black pubescence; abdomen yellowish, wider than thorax and apparently widest at hind margin of 2nd segment: 1st segment yellow and black; 2nd-4th segments same as in *Ischiodon scutellaris*, but black band broader than in the former; 5th segment with a black variable marking similar to reversed "T". (pl. 10, G) ..... *Paraxanthogramma nakamurae*

8. Wings with a broad dark brown band from front to hind margin nearly occupying median two thirds; oval cavity narrow and long; abdomen yellowish brown; 2nd segment brownish black except a pair of large irregularly oval spots placed obliquely from anterior corners, their inner ends occasionally connected; 3rd and 4th each along hind margin with a broad brownish black band occupying one-half to two thirds of the length of the segment, extending from side to side; marking of 5th segment usually having an irregular triangular blackish spot; body large, length about 13 mm. (pl. 11, K) ..... *Asarcina aegrota*

Wings clear, without distinct dark brown band as mentioned above. 9

9. Thorax shining aeneus black, however, without grey stripes. 10
   Thorax less glossy aeneus black, with a pair of inconspicuous grey stripes at least on fore portion 11

10. Scutellum with erect, blackish pubescence; face densely covered with whitish yellow tomentum and pubescence, central bump pale and shiny; abdomen yellow: 1st segment blackish except lateral sides narrowly yellow, fore and hind of 2nd segment with brownish black band broadened on both sides and middle remaining a pair of yellow oval spots, which is fused on inner side; fore and hind margins of 3rd and 4th with a brownish black band; 5th with an indefinite blackish transverse marking; body generally larger, length 8-12 mm. (pl. 10, H) .....*Metasyrphus confrater*
    Scutellum covered with dull yellow pubescence; face almost all free from dense tomentum and pubescence, central bump dull yellow to light brown; abdomen yellow: 1st segment steel bluish to bronzy black; 2nd, 3rd and 4th segments with a transverse "H" shape brownish black marking, however, as median strip usually interrupted in male, a pair of rather large, yellow and irregularly sub-oval spots apparently; 5th segment indistinctly darkened in middle; body rather smaller, length 7-8 mm. (pl. 11, I).....*Metasyrhus corollae*

11. Thorax steel bluish black, less shiny; abdomen distinctly broader than thorax, lateral margins of 2nd-4th tergites rolled down, at least lateral margins of 2nd-3rd tergites marginated 12
    Thorax glossy aeneus black; abdomen nearly as wide as thorax. 13

12. Eyes with dense brown pubescence, central bump brownish to blackish; scutellum brownish to blackish, finer pubescent; abdomen black, tinged indigo: 1st segment shining and steel bluish black; 2nd segment with a pair of transverse narrow triangular spots, indigo yellowish on its hind third, 3rd segment bears a rather narrow band, indigo yellowish on front third, 4th blackish and with a narrow greyish yellow band tends to interrupt at frontal middle third, 5th steel bluish black, shiny. (pl. 11, J) .....*Syrphus serrarius*
    Eyes bare, central bump yellowish and broader, scutellum with rather stronger blackish pubescence; abdomen yellow: 1st segment blackish; fore and hind part of 2nd segment with brownish black band forming a pair of large, oval, well separated yellow spots on across center of the segment, spots distinctly passing over the sides and reach to cephalo-lateral corners, fore and hind of 3rd, 4th segments each with a brownish black, more or less sinuate band, however, hind black band of 4th keeps a short distance from hind segmental margin; 5th segment yellow except blackish fore margin. (pl. 11, L)..... *Syrphus vitripennis*

13. Central bump of face yellowish, antennae brownish-yellow; abdomen brawnish-yellow: 1st segment steel bluish black except yellowish sides, 2nd segment bears variable marking, usually a narrow blackish band with a median basal stripe on front half and a uniformly wide, extending

to sides, blackish band on hind margin, 3rd with a narrow blackish band slightly curved or fractured in center on front third and a wider black band on hind margin, 4th similarly marked to 3rd but hind band placed at distance from hind margin or with an irregular spot medially. (pl. 11, M)..... *Epistrophe balteata*

Central bump to epistoma blackish, antennae brownish-black; abdomen brownish-yellow: 1st segment with a pair of brownish-black spots laterally, hind margin of 2nd segment with a brownish band united with median longitudinal narrow line, 3rd and 4th each with a hind blackish band, however, in the latter scarely separated from hind segmental margin, marking of 5th similar to 4th. (pl. 11, N)..... .....*Epistrophe horishana*

DESCRIPTION OF EGG OF SOME APHIDOPHAGOUS SYRPHIDS OF TAIWAN (plate 11)

1. Body small, length 0.62-0.78 mm, width 0.25-0.31 mm; surface entirely with thick slender stripe-like process, width of stripe frequently less than the distance between stripes. (pl. 11, O)..... *Ischiodon scutellaris*
2. Body medium-size, length 0.78-1.09 mm; width 0.28-0.37 mm; surface entirely with rather thick and comparatively stouter stripe-like process, width of process frequently longer than the distance between processes. (pl. 11, S)..... *Epistrophe balteata*
3. Body medium-size, length about 0.93 mm, width about 0.39 mm; surface entirely pitted shallowly and with distinct thick short palisade-like process among them. (pl. 11, P) ..... *Asarcina aegrota*
4. Body medium-size; length about 0.9 mm, width about 0.36 mm; surface smooth, entirely with comparatively sparser conic process distinctly. (pl. 11, R) ... .*Syrphus vitripennis*
5. Body large, length about 1.2 mm, width about 0.4 mm; surface entirely with thick slender stripe-like process as in *Ischiodon scutellaris*, sometimes short palisade-like process locally among them, very easily distinguished from *I. scutellaris* by size. (pl. 11, Q) ..... *Metasyrphus confrater*

KEY TO LARVA OF IMPORTANT APHIDOPHAGOUS CHAMAEMYIID AND SYRPHIDS OF TAIWAN

1. Two caudal spiracular processes far separated (fig. 27, B), caudal spiracular process pointed and approximately one-half of the diameter of the caudal segment, full grown larva greenish smaller than 4.0 mm; with distinct processes on most segments. (fig. 27, B) .....*Leucopis* sp.

   Two caudal spiracular processes contiguous or fused, caudal spiracular process never pointed, full grown larva longer than 5.0 mm..... 2
2. Caudal spiracular process shorter than the transverse diameter of distal spiracular area (d. s. area) (pl. 12, U) 3

   Caudal spiracular process distinctly longer than the transverse diameter of distal spiracular area 6

3. Body with distinct chalaza and thick setulae, surface of body rough 4
   Body with indistinct chalaza but without setulae, surface of body comparatively smooth; body flat, grayish black, with whitish lateral margin; postmedial area with a white acute triangular marking; cephalad broad, subequal to the width of body; the 2 subround distal spiracular area with a hillock-like surface, and bearing 3 slender spiracular tubercles; caudal spiracular tubercle B and C frequently sub-parallel; full grown larva about 15 mm long. (pl. 12, U, D) ..... *Asarcina aegrota*
4. Inner side of the distal spiracular areas with a distinct small blackish brown horn-like process; caudal spiracular process nearly as long as the diameter of distal spiracular area; body yellowish white, with distinct white transverse plicae mediastinally; lateral side brownish black; blackish brown arcuate marking along the white plicae anteriorly forming a scale-like design; medial groove between 2 distal spiracluar area distinct, caudal spiracular tubercle B situated nearer to caudal spiracular tubercle C than to caudal spiracular tubercle A; caudal spiracular tubercle B and C frequently arranged in "ヽヽ" shape. (pl. 12, U, D)..... *Syrphus serrarius*
   Inner side of the 2 distal spiracular areas without process except the spiracular tubercles; caudal spiracular process present as a plate or just as a swelling; body without scale-like design as mentioned above 5
5. Body with granular surface; full grown larva 10-12 mm long; conspicious mediastinal line yellowish or brownish, sometimes whitish-gray or brownish-gray; the 2 parted suboval distal spiracular areas without any other process except 3 pairs of swollen spiracular tubercle, frequently with caudal spiracular tubercle B and C sub-parallel, and the former always placed higher than the latter tubercle A angled about 45° to upper outer side and with greater distance to caudal spiracular tubercle B than that between caudal spiracular tubercle B and C. (pl. 12, U, B)..... ..... *Ischiodon scutellaris*
   Body with numerous brown setulae; full grown larva about 14 mm long; without conspiciously coloured mediastinal line; the 2 round or hexagonal distal spiracular area usually fused or contiguous presenting an inconspicuous groove; caudal spiracular tubercle C distinctly shorter than other 2. (pl. 12, U, E) ..... *Metasyrphus confrater*
6. Caudal spiracular process pretty long, 3-4 times as long as the transverse diameter of distal spiracular area..... 7
   Caudal spiracular process 1-2 times as long as the transverse diameter of distal spiracular..... 8
7. Caudal spiracular process fairly long, 3-4 times as long as the transverse diameter of distal spiracular area; dorsal view of the 2 caudal spiracular process fused into one stout tube, without fusing trace, except the separating apical part; distal spiracular area sub-pentagonal or subrounded caudal spiracular tubercles with subequal distance; arrangement of caudal spiracular tubercles as shown in (pl. 12, J) and (pl. 12, A)..... ..... *Paragus serratus*

Dorsal view of the 2 caudal spiracular processes with a groove as the fusing trace; distal spiracular area D without prominent process as mentioned above; the 2 distal spiracular areas separated and concaved distinctly in inner side; caudal spiracular tubercles slender and unicoloured with distal spiracular areas; body flat, green, with distinct transverse plicae; chalaza small; full grown larva 10.0-13.0 mm long. (pl. 12, I, R) .... *Epistrophe horishana*

8. Body with prominent chalaza and granular surface; caudal spiracular process relatively longer, 1.5-2.0 times as long as the transverse diameter of distal spiracular area; apical part of caudal spiracular process narrower than its basal part; caudal spiracular tubercle slender; caudal spiracular tubercle C usually longer than A and B; the 2 suboval distal spiracular area usually fused and with a indistinct groove between them; caudal spiracular process end of lateral view with an oblique contour body mediastinally present a white band, pointed anteriorly and dotted by some blackish brown marking; full grown larva 11-15 mm long. (pl. 12, U, G)... .....*Syrphus vitripennis*

Body with indistinct setae and smooth surface; caudal spiracular process relatively shorter 9

9. Body stout, cephalic end narrow and pointed; full grown larva about 11 mm long; the 2 larger subsquare or sub-rounded distal spiracular areas fused and with longer caudal spiracular tubercles arranged as follow: caudal spiracular tubercle A and B angled about 45° to upper outer side and lower outer side in median region of area A and B, caudal spiracular tubercle C directing downward or sometimes inclined slightly in area C; caudal spiracular tubercle B and C about the same distance to the cross horizontal line (illustrated at the bottom of the page); body with whitish slender band mediastinally from cephalic 1/3 to 10th abdominal segment, both sides of this slender band pigmented whitish gray and reddish brown. (pl. 12, U, H)..... *Epistrophe balteata*

Body smaller and slender; full grown larva 7-8.5 mm long; the 2 small subrounded distal spiracular areas partly distinctly; smaller caudal spiracular tubercles laterally in outer side of each distal spiracular area and with a greater distance between caudal spiracular tubercles of each area arranged as follow: caudal spiracular tubercle A and C angled about 45° to upper outer side and lower outer side in area A, D and area B, C respectively; caudal spiracular tubercle C almost transverse on the cross horizontal line; body greenish, with a slender brownish band mediastinally. (pl. 12, U, E).....*Sphaerophoria formosana*

KEY TO THE PUPA OF IMPORTANT APHIDOPHAGOUS CHAMAEMYIID AND SYRPHIDS OF TAIWAN (pl. 12)

1. Caudal spiracular processes far separated; body small, about 2.5 mm long, 1.0 mm wide. (fig. 27, C) .....*Leucopis* sp.

Caudal spiracular processes close together; body large, above 5.0 mm in length. 2

2. Body in "Balteata type"; (dorsum with a slope from the median to the distal in profile) caudal spiracular process directed backward-up 3

Body in "Scutellaris type"; (most part of dorsum sub-parallel to the bottom in profile) caudal spiracular process directed backward 7

3. Body with distinct chalaza 4

Body smooth, without chalaza or with indistinct ones 5

4. Caudal spiracular process fairly long, about 4 times as long as the transverse diameter of a distal spiracular area; distal spiracular area square, brown and separated; caudal spiracular tubercles brownish black, and arranged on 3 corners of each square distal spiracular area; distal spiracular area D with a horn-like process each; body yellowish, small and slender; length 4-5 mm; width 1.7-2.3 mm; height 1.5-2.1 mm. (pl. 12 T, 13 D) ... . *Paragus tibialis*

Caudal spiracular process short, the process in distal spiracular area D vestigial as a small thorn; caudal spiracular tubercles brownish-black and arranged as in larva; distal spiracular area brown and separated; body length about 5.5 mm; width about 2.3 mm; height about 2.3 mm; chalaza fairly large; dorsum strongly arcuate in lateral aspect; purplish-brown dorso-medially, fulvus laterally. (pl. 12 J, 13 B) .... *Paragus serratus*

5. Dorsum with definite transverse plicae; distal part comparatively broader; body colour dark, brownish to blackish brown; distal spiracular area and caudal spiracular tubercle unicoloured in brownish black; spiracular tubercles slender and arranged as in larva; body length 6.0-9.0 mm; width 3.2-4.7 mm; height 3.0-4.2 mm. (pl. 12 M, 13 H) .... *Asarcina aegrota*

Dorsum without plicae as mentioned above; distal part rather narrowed; body colour generally light with delicate, smooth surface; distal spiracular area yellowish brown; caudal spiracular tubercle browish black 6

6. Body large; length 5.8-8.1 mm; width 2.1-3.1 mm; height 2.5-3.3 mm; yellowish white to yellowish brown; dorsum frequently with brown spots mediastinally; the 2 large distal spiracular area fused and with longer caudal spiracular tubercles arranged as in larva. (pl. 12 Q, 13 B) ..... *Epistrophe balteata*

Body small and slender; length 5.0-6.0 mm; width 1.6-2.1 mm; greenish to yellowish brown; dorsum without spots as mentioned above except a mediastinal brown band usually from median to caudal spiracular process; the 2 small distal spiracular area separated, with smaller caudal spiracular tubercles laterally in outer side of each distal spiracular area and arranged as in larva. (pl. 12 L, 13 A) ..... *Sphaerophoria formosana*

7. Distal spiracular area without other process except the spiracular tubercles... 8

Distal spiracular area with process in addition to the spiracular tubercles ... 9

8. Caudal spiracular tubercles sub-equal in size; tubercle B and C sub-parallel

the former always placed distinctly higher than the latter; all spiracular tubercles brown and with black band margin, and conspicuously swollen, distal spiracular areas separated distinctly, brownish yellow and outlining the spiracular tubercles neatly; body nearly cylindrical and comparatively slender; length 6.2-8.0 mm; width 2.9-3.2 mm; height 2.7-3.0 mm; greenish to brown and green. (pl. 12 K, 13 G) ..... *Ischiodon scutellaris*

Caudal spiracular tubercles different in size; tubercle B not placed much higher than C as in the above; tubercle C usually longer than A and B; distal spiracular area blackish brown or black; shape of body usually similar to that of the above except generally with blackish brown granule on the surface; body length 6.0-7.0 mm; width 3.2-3.7 mm; height 2.6-3.0 mm. (pl. 12 S, 13 F) ..... *Metasyrphus corollae*

9. Caudal spiracular process shorter than the transverse diameter of distal spiracular area; distal spiracular areas sub-round with irregular margin, indistinct groove narrow and shallow between the areas; area D with process like a small spiracular tubercle; spiracular tubercles arranged as in larva; body length about 8.5 mm; width about 4.2 mm; height about 3.8 mm. (pl. 12 N, 13 I)..... *Metasyrphus confrater*

Caudal spiracular process longer or as long as the transverse diameter of distal spiracular area 10

10. Caudal spiracular process as long as the transverse diameter of distal spiracular area; the 2 distal spiracular areas generally yellowish and with a horn-like process in distal spiracular area D. each; distal spiracular tubercles arranged as in larva; body with a shallow brownish-black groove mediastinally; dorsum transversely with a pair of curved brown markings; body length about 7.0 mm; width about 3.5 mm; height about 3.3 mm. (pl. 12 O, 13 J)..... *Syrphus serrarius*

Caudal spiracular process 1.5-2.0 times as long as the diameter of distal spiracular area; the 2 distal spiracular areas with a spiracular tubercle-like process in area D each; the spiracular tubercles slender and arranged as in larva; distal spiracular area brownish black; body length 7.0-9.0 mm; width 3.6-4.6 mm; height 3.3-4.2 mm. (pl. 12 P, 13 C)..... ..... *Syrphus vitripennis*

III. Biology of aphid predators

Aphid predators for biological observation were collected and brought from citrus groves or vegetable fields into the insectary. The temperature of the insectory was maintained at 22-24°C. Eggs of each species after hatching were fed with aphids. Aphid species were from the same host plants, until these aphids were exhausted. Then they were fed with aphids from sorghum or corn to complete their life cycle.

The aphid consumption was calculated by counting the number of aphids before and after feeding and then subtracting. There are 16 species of lady beetles,

14 species of hoverflies, 1 species of chamaemyiid, 2 species of aphis lions and 1 species of hemerobiid feeding on aphids infesting citrus, vegetables, tobacco, other crops and wild plants. The biology of each species is described below:

APHIS LIONS, HEMEROBIID AND OTHERS

Chrysopa septempunctata Wesmael (fig. 7)

Adults lay eggs on the leaf or twig of aphid host plants. There are always 10 or more eggs laid together and each egg has a long stalk which is little bent due to the heavy weight. After hatching, the larva feeds on aphid with its powerful mandibles from both sides of victim and discards empty aphid skin to search for further prey. There are two moults to complete larval development. The life cycle takes 3-5, 5-6, 8-12, 6-12, 45-65 and 65-80 days for the development to egg, larva, pupa, preoviposition, oviposition and longivity respectively. Number of aphids consumed, larval and pupal stages vary according to the aphid species given as food, i. e., *Myzus persicae* 758-1,064 individuals, 10-12 and 16-19 days; *Aphis spiraecola* 864-1,080 individuals, 13 and 22-24 days, *Aphis gossypii* 1,023-1,127 individuals, 11-13 and 24-25 days; *Lipaphis erysimi* 384-431 individuals, 14 days respectively. However, if they feed on *Toxoptera citricida*, the larvae usually die in or after the first moult 3-6 days after eating 53-284 individuals, but they feed on *Aphis nerii* safely and complete their life cycle. *Toxoptera aurantii*, *Rhopalosiphum padi* are also eaten.

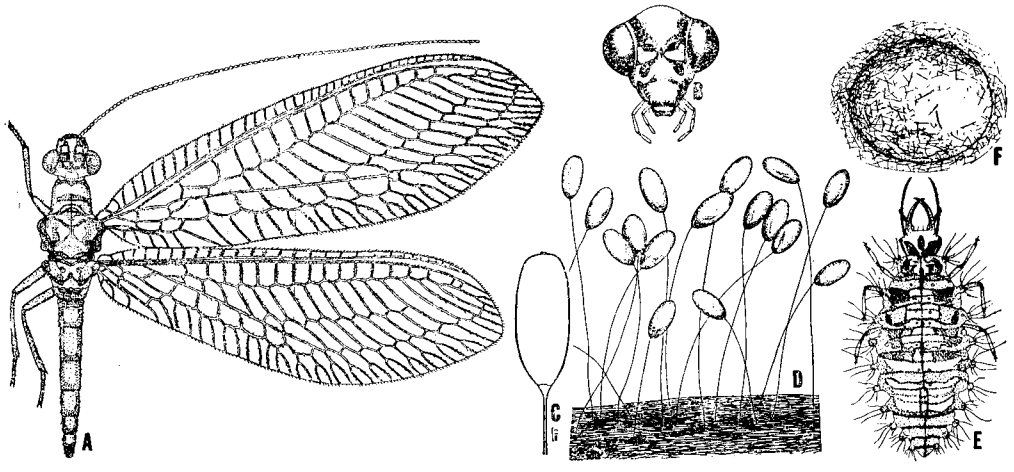


Fig. 7. *Chrysopa septempunctata*: adult (A); head frontal aspect (B); egg (C); egg cluster (D); larva (E); cocoon (F).

Chrysopa boninensis Okamoto (fig. 8)

Adults lay eggs singly on leaves or twig and this makes them difficult to find. The eggs have egg stalk. Besides aphids this species also feeds on mites and other soft bodied insects. The feeding habit is the same as with *C. septempunctata* but

after feeding the larvae usually load their victims on their back; this is a good indication of what kinds of preys were eaten. It takes 2-4, 13-16, 12-14, 13-16 and 40-45 days to complete the development of egg, larva, pupa, preoviposition and oviposition respectively. The number of aphids consumed, and the length of larval and pupal stages vary with different aphid species as food, i. e., *Myzus persicae* 392-595 individuals, 12-13 and 15-17 days, *Aphis spiraecola* 661-1,076 individuals, 13-15 and 13-16 days respectively. However, if it feeds on *Toxoptera citricida* it dies in first moult 9-11 days after eating 50-109 individuals.

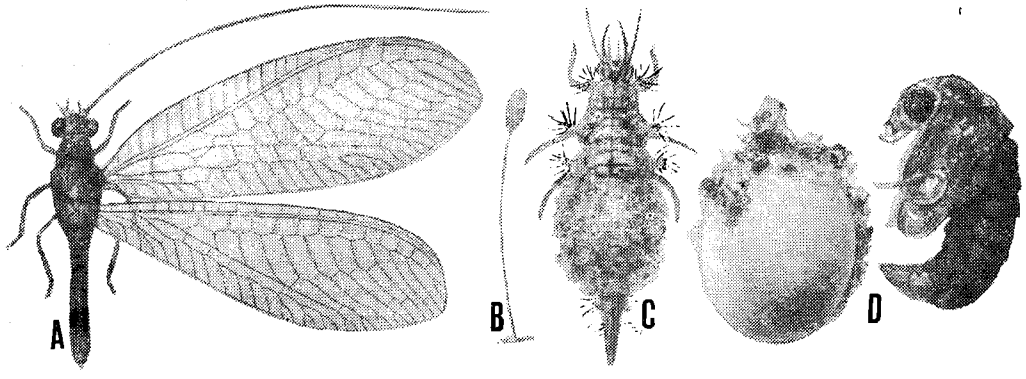


Fig. 8. *Chrysopa lotinensis*: adult (A); egg (B); larva (C); pupa and cocoon (D).

Ankyloptera octopunctata Fabricius*

It also distributed in India, Java, Philippines, South China and Ryukyu. Larvae feed on *Aphis spiraecola, A. gossypii, Toxoptera citricida, T. aurantii* and *Ceratovacuna lanigera.*

Eumicromus sauteri Esben-Peterson (fig. 9)

Larvae feed on *Aphis spiraecola, A. gossypii, Toxoptera aurantii, T. citricida, Ceratovacuna lanigera* and *Rhopalosiphum padi.* It takes 3-5, 5-6, 8-12, 4-6, 25-45 days to complete the development of egg, larva, pupa, preoviposition, oviposition respectively. 500-900 eggs were laid by one female during its life with 30-50 being laid per day.

Orius sp. (Anthocoridae, Hemiptera)

Nymphs and adults feed on *Aphis spiraecola, A. gossypii.*

Anytis sp. (Anystidae, Acarina, Arachanida)

It feeds on *Aphis spiraecola, A. gossypii, Toxoptera aurantii, Myzus persicae, Lipaphis erysimi.*

* For lack of the complete specimens of this species, it is not included in the key to aphidophagous neuropteroids (p. 42).

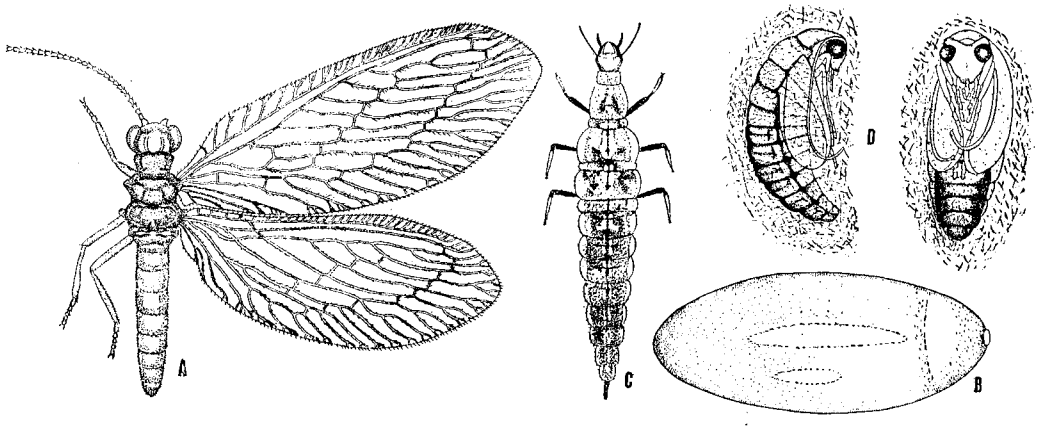


Fig. 9. *Eumicromus sauteri*: adult (A); egg (B); larva (C); pupa (lateral and ventral aspect) and cocoon (D).

Coccinellids

Lemnia swinhoei Crotch (fig. 10)

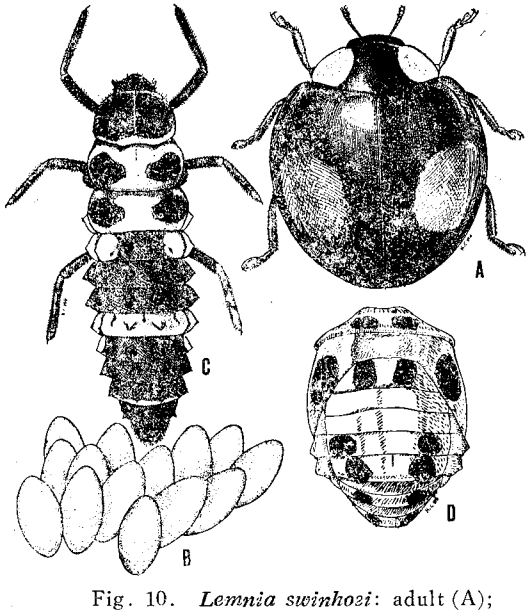


Fig. 10. *Lemnia swinhoei*: adult (A); eggmass (B); larva (C); pupa (D).

Lemnia swinhoei Crotch is the most abundant of aphid feeding coccinellids on this island, as it has a high fecundity and can feed on many aphid species. Even *Aphis nerii* which is toxic to most aphid feeding coccinellids, can be eaten and the life cycle completed. However, *Lipaphis erysimi* is toxic to the larvae and if fed the larvae usually died in 2nd or 3rd instar. The adults can feed on *Lipaphis erysimi* but lay fewer eggs than if fed on other aphid species. Fewer eggs are also laid if the adults are fed on *Aphis nerii*. It flies to lac insect infesting plant lyche and takes sweet secretion during warm winter.

Eggs of *Lemnia swinhoei* can survive at 10°C and larvae can complete their life cycle at 15°C. The optimum development temperature is 25-28°C. It takes 3-4, 1-2, 1-2, 2-3, 4-5, 10-11, 5-6, 15-21, 15-20 and 135-150 days to complete the development of egg, 1st, 2nd, 3rd and 4th stadium, full larval stage, pupa, one generation, preoviposition and oviposition respectively. 1,800-2,500 eggs were laid by one female with 16-24 laid per day.

The number of aphids consumed and the development of full larval stages varied if fed on different aphid species, i. e. *Myzus persicae* 254-342 individuals and 12-14 days, *Aphis gossypii* 374-536 individuals and 10-11 days, *Aphis spiraecola* 235-362 individuals and 10-12 days, *Toxoptera citricida* 379-397 individuals and 13 days, *Rhopalosiphum maidis* 245-413 individuals and 9-12 days respectively. *Aphis gossypii* and *A. spiraecola* seems to be the most suitable prey with these as food *L. swinhoei* reached high maturity, high fecundity, quick development and more aphids were consumed.

It can also feed on *Brevicoryne brassicae*, *Rhopalosiphum padi*, *Toxoptera aurantii*, *Aphis craccivora*, *Sinomegoura citricola*, *Acyrthosiphon pisum* and *Oregma bambusicola*. *Oregma bambusicola* of young bamboo is a food source of the over-wintering aphid in cold and wet northern parts of Taiwan. It usually co-exists with *Synonycha grandis* and *L. plagiata* on young bamboo infested with *Oregma bambusicola*.

Lemnia biplagiata Swartz (fig. 11)

The population of *Lemnia biplagiata* Swartz in Taiwan is just less than *L. swinhoei* Crotch and the larvae can feed on *Aphis nerii* to complete their life cycle. If the larvae fed on *Lipaphis erysimi* they usually die in the 3rd stadium. The adults can feed on *Lipaphis erysimi* and survive but lay less eggs. However, the same amount of eggs were laid as if fed on *Aphis nerii*.

The optimum development temperature of *Lemnia biplagiata* is similar to *L. swinhoei*, but the eggs can not survive in 10°C. It takes 3-4, 2-3, 2-3, 2-3, 4-5, 13-15, 5-6, 21-25, 18-19 and 72-142 days to complete the development of egg, 1st, 2nd, 3rd and 4th stadium, full larval stage, pupa, one generation, preoviposition and oviposition respectively. 1,500-2,500 eggs were laid by one female and 16-48 eggs laid per day.

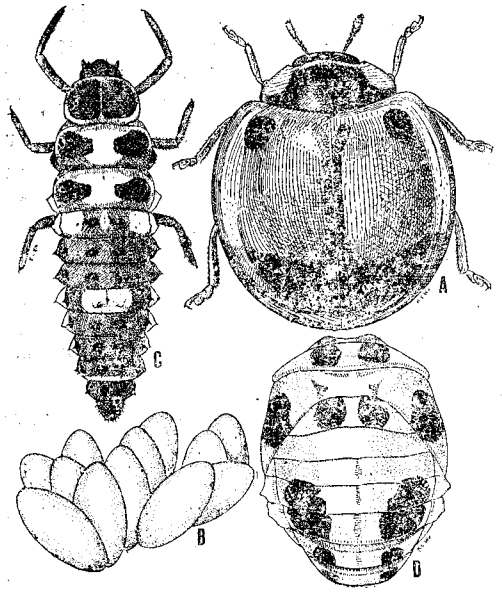


Fig. 11. ***Lemnia biplagiata***: adult (A); eggmass (B); Larva (C); pupa (D).

The number of aphids consumed and the development of full larval stages varied if fed on different aphid species, i. e. *Myzus persicae* 234-339 individuals and 15-19 days, *Aphis gossypii* 318-399 individuals and 12 days, *Aphis spiraecola* 324-335 individuals and 12 days, *Toxoptera citricida* 342-541 individuals and 12-15 days, *Rhopalosiphum maidis* 284-345 individuals and 12 days, *Aphis nerii* 340-414 individuals and 11-12 days respectively. *Aphis gossypii* seems to be the most suitable species because it has high fecundity.

Rhopalosiphum padi, Brevicoryne brassicae, Lipaphis erysimi, Toxoptera aurantii, Aphis craccivora, Sinomegoura citricola, Acyrthosiphon pisum and *Sitobion avenae* are also eaten by this species. It can more easily survive the typhoon season than other aphid feeding coccinellids.

Menochilus sexmaculatus Fabricius (fig. 12)

Menochilus sexmaculatus Fabricius is also common on this island, with a population density just less than *Lemnia swinhoei* Crotch and *L. biplagiata* Swartz. Its larvae fed on *Toxoptera citricida* usually die in 3rd stadium but they could feed on *Aphis nerii* and complete their life cycle. The adults fed on *Aphis nerii* could lay the normal number of eggs which was not less than *Lemnia swinhoei* and *L. biplagiata* fed on the same aphid. Moreover, the adults fed on *Aphis spiraecola* could lay more eggs.

The optimum development temperature is 28-30°C which is a little higher than preceding 2 *Lemnia* spp. It takes 2-4, 1-2, 1-2, 2-3, 2-3, 9-10, 4-7, 16-21, 5-15, 75-128 days to complete the development of egg, 1st, 2nd, 3rd and 4th stadium, full larval stage, pupa, one generation, preoviposition and oviposition respectively, 1,800-2,800 eggs were laid by one female and 28-105 were laid per day.

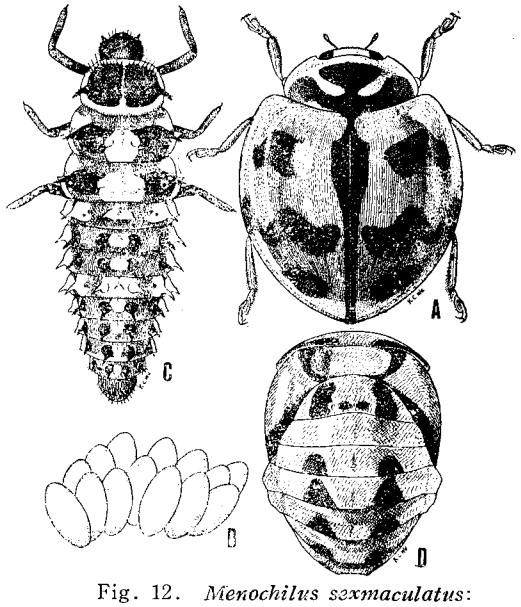


Fig. 12. *Menochilus sexmaculatus*: adult (A); eggmass (B); larva (C); pupa (D).

The number of aphids consumed and the development of full larval stage depended on the aphid species given as food, i. e., *Myzus persicae* 215-324 individuals, 9-10 days, *Aphis gossypii* 306-516 individuals, 8-9 days, *A. spiraecola* 132-299 individuals, 9-10 days, *Lipaphis erysimi* 213-254 individuals, 16-21 days respectively.

It was comparatively easily killed by cold spells in January and February (below 10°C) as well as parasited by *Tetrastichus* sp. (Eulophidae) in the pupal stage if it takes a long pupation period because of colder weather than usual in November and December.

Rhopalosiphum padi, Aphis craccivora, Toxoptera aurantii, Sinomegoura citricola, Acyrthosiphon pisum and *Sitobion avenae* were also observed as its food aphids.

Propylaea japonica Thunberg (fig. 13)

Propylaea japonica Thunberg is widely distributed in cold temperate and subtro-

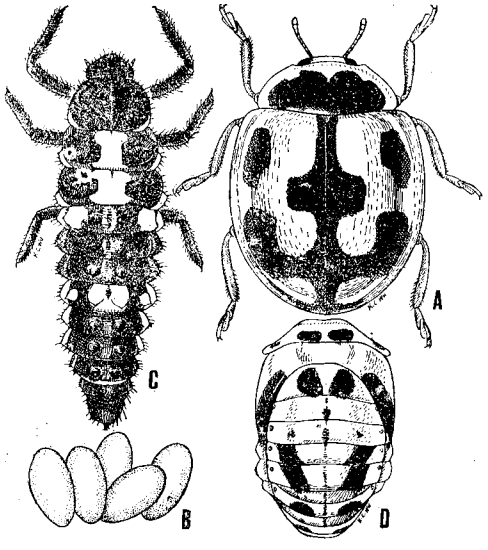


Fig. 13. *Propylaea japonica*: adult (A); eggmass (B); larva (D); pupa (D).

pical Eastern Asia. It is a comparatively small coccinellid which can feed on aphid species infesting citrus and cruciferous plants. There is no difference in appetite and it feeds normally on *Toxoptera citricida* and completes its life cycle.

The optimum development temperature of *Propylaea japonica* is similar to other coccinellids, 25-28°C. It takes 3-4, 1-2, 1-2, 2, 2-3, 9-12, 4-6, 16-22, 8-15, 68-150 days to complete the development of egg, 1st, 2nd, 3rd and 4th stadium, full larval stage, pupa, one generation, preoviposition and oviposition respectively, 1,000-1,500 eggs were laid by one female and 12-32 eggs were laid per day.

The number of aphids consumed and the development of full larval stage varied according to the different aphid species given as food, i. e., *Myzus persicae* 273-314 individuals and 13 days, *Aphis gossypii* 365-453 individuals and 7-8 days, *Aphis spiraecola* 396-433 individuals and 7-8 days, *Toxoptera citricida* 244-364 individuals and 8-14 days and *Lipaphis erysimi* 231-268 individuals and 14 days respectively.

Brevicoryne brassicae, *Rhopalosiphum padi*, *Toxoptera aurantii*, *Aphis craccivora*, *Acyrthosiphon pisum* and *Sitobion avenae* are also observed as its food aphids.

Coccinella septempunctata bruckii Mulsant (fig. 14)

Coccinella septempunctata Linne is a world wide species but var. *bruckii* Mulsant restricted to the Orient. The occurrence on this island is almost as common as the preceding 4 coccinellids. However, it seems to be more common in the cross high way area and checks *Brevicoryne brassicae* quite often. On low land it feeds on *Myzus persicae*, *Lipaphis erysimi* on cabbages and *Rhopalosiphum maidis* on corn and is more often present than *Lemnia swinhoei* and *Propylaea japonica*. The larvae fed on *Toxoptera citricida*, *Aphis nerii* and *Akkaia taiwana* usually died in 3rd and 4th stadium. Adults safely feed on *Aphis nerii* but stop egg laying.

The optimum development temperature is 25-28°C., eggs could hatch at 10°C and larvae could complete life cycle at 35°C. It takes 4-5, 2-3, 2-3, 2-3, 3-4, 14-18, 6-8, 24-35, 16-30, 23-69 days to complete the development of egg, 1st, 2nd, 3rd and 4th stadium, full larval stage, pupa, one generation, preoviposition and oviposition respectively. 650-1,800 eggs were laid by one female and 24-98 were laid per day.

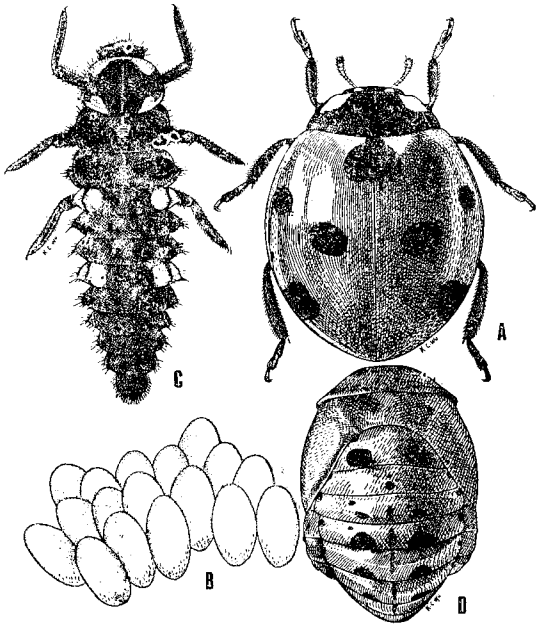


Fig. 14. *Coccinella septempunctata bruckii*: adult (A); eggmass (B); larva (C); pupa (D).

the preceding *Coccinella septempunctata bruckii* Mulsant in the low lands of Taiwan. Larvae fed on *Toxoptera citricida* died in 2nd stadium. *Aphis nerii* was toxic to the larvae too. Adults fed on *Lipaphis erysimi* usually lay only a few eggs.

The optimum development temperature is 14-28°C. It takes 3-4, 2-3, 2-3, 3-4, 4-5, 12-15, 8-11, 23-31, 20-28, 38-65 days to complete the development of egg, 1st, 2nd, 3rd and 4th stadium, full larval stage, pupa, one generation, preoviposition and oviposition respectively, 485-1,200 eggs were laid by one female and 16-65 were laid per day.

The number of aphids consumed and the development of full larval stage varied if fed on different aphid species, i. e., *Myzus persicae* 514-669 individuals and

The number of aphids consumed and the development of full larval stage varied if fed on different aphid species, i. e., *Myzus persicae* 469-735 individuals and 11 days, *Aphis gossypii* 694-1,114 individuals, 13-14 days, *A. spiracola* 1,085-1,412 individuals, 17-19 days, *Lipaphis erysimi* 712-833 individuals, 13 days, *Rhopalosiphum maidis* 881-1,045 individuals, 12 days, *Hysteronura setariae* 414-459 individuals, 13 days respectively.

Brevicoryne brassicae, Aphis craccivora, Acyrthosiphon pisum were also observed as food aphids.

Coccinella repanda Thunberg (fig. 15)

Coccinella repanda Thunberg is a tropical aphid-feeding coccinellids. The population is not so heavy as

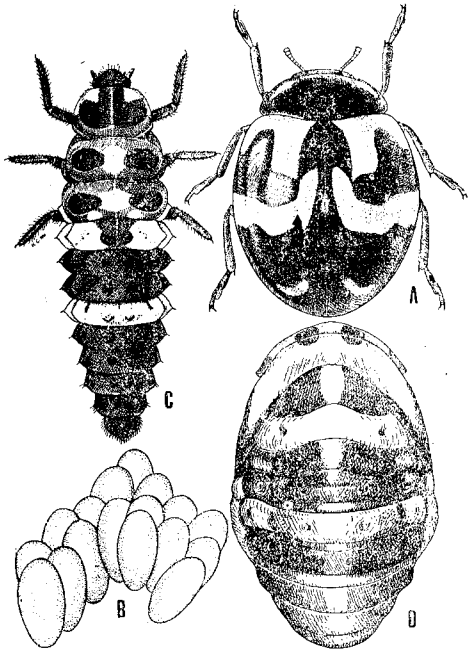


Fig. 15. *Coccinella repanda*: adult (A); eggmass (B); larva (C); pupa (D).

11-12 days, *Aphis gossypii* 564-602 individuals and 10-12 days, *A. spiraecola* 1,183-1,251 individuals and 11-14 days, *Lipaphis erysimi* 453-511 individuals and 12-15 days and *Longiungius sacchari* 843-1,200 individuals and 9-10 days respectively.

Coccinella octopunctata Fabricius (fig. 16)

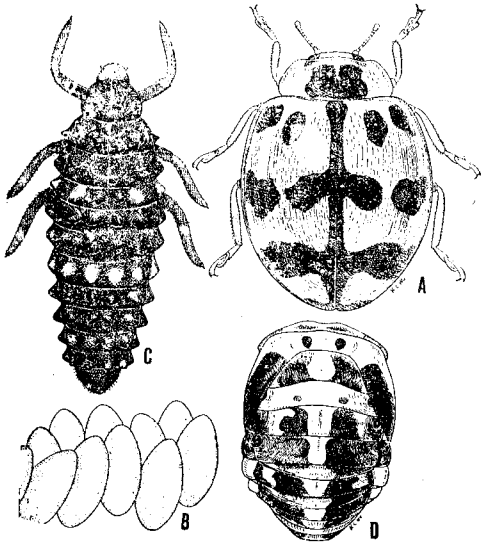


Fig. 16. *Coccinella octopunctata*: adult (A); eggmass (B); larva (C); pupa (D).

The life habit of *Coccinella octopunctata* Fabricius is the same as *C. repanda* Thunberg, but the population is much lower. The larvae fed on *Toxoptera citricida* usually died in the 2nd stadium, adults fed on *Lipaphis erysimi* laid the normal amount of eggs.

The optimum development temperature was 25-28°C. It takes 2-4, 2-3, 2-3, 2-3, 5-6, 11-15, 5-7, 19-26, 28-35 and 40-48 days to complete the development of egg, 1st, 2nd, 3rd and 4th stadium, full larval stage, pupa, one generation, preoviposition and oviposition respectively. 900-1,800 eggs was laid by one female and 20-83 were laid per day.

The number of aphids consumed and the development of full larval stage varied if fed on different aphid species, i. e., *Aphis gossypii* 925-1,232 individuals and 16-17 days, *Aphis spireacola* 719 individuals and 19 days *Loungiungius sacchari* 830-1,049 individuals and 17-19 days respectively.

Leis dimidiata Fabricius (fig. 17)

Leis dimidiata Fabricius is a rare aphid-feeding coccinellid as the larvae fed on *Toxoptera citricida, Lipaphis erysimi* and *Aphis nerii* died in 1st, 2nd, 3rd or 4th stadium. Adults fed on *Toxoptera citricida* and *Lipaphis erysimi* lay the normal number of eggs and the fecundity is the same as *Lemnia swinhoei* and *L. biplagiata* fed on *Toxoptera citricida.* Moreover, if fed on *Lipaphis erysimi* more eggs are laid. Unfortunately if fed on *Aphis nerii* death was very rapid.

This species has been introduced to Florida, U. S. A. from South China and established well in citrus groves. It may be that *Toxoptera citricida* does not occur in that State.

It takes 4-5, 1-2, 1-2, 3-4, 5-6, 14-19, 6-8, 33-45, 18-32, 23-68 days to complete the development of egg, 1st, 2nd, 3rd and 4th stadium, full larval stage, pupa, one generation, preoviposition and oviposition respectively. 350-700 eggs were laid by

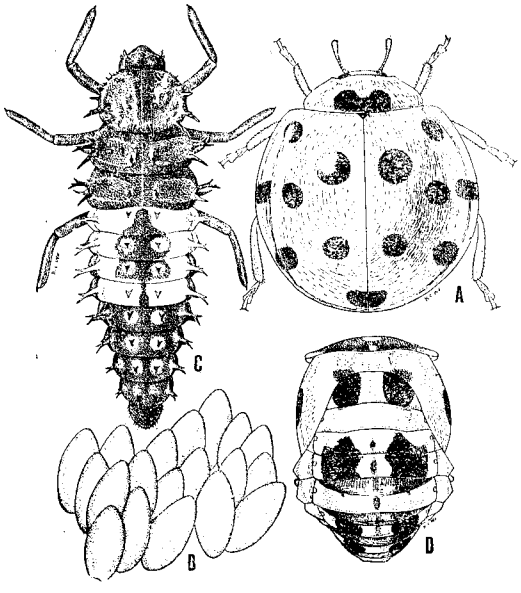


Fig. 17. *Leis dimidiata*: adult (A); eggmass (B); larva (C): pupa (D).

one female. It usually feeds on *Paurocephala psylloptera* Crawford (Psyllidae, Homoptera; host plant: mulberry) and completes one generation quicker than f fed on *Aphis spiraecola*.

The number of aphids consumed and the development of full larval stage varied if fed on different aphid species, i. e., *Myzus persicae* 835-1,065 individuals and 14-15 days, *Aphis spiraecola* 1,180-1,240 individuals and 9-10 days, *Longiunguis sacchari* 1,661-1,744 individuals and 8-9 days, *Hysteronura setariae* 684-782 individuals and 15 days respectively.

Leis axyridis Pallus (fig. 18)

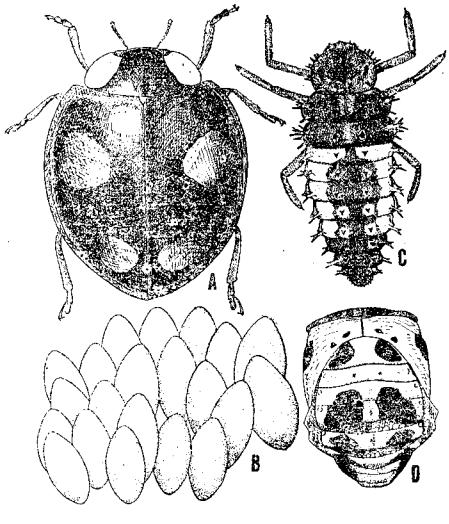


Fig. 18. *Leis axyridis*: adult (A); eggmass (B); larva (C); pupa (D).

Leis axyridis Pallus was only found once on this island in 1969, but it is very common in the cold and temperate zones of Eastern Asia. Mr. T. C. Hsu observed it feeding on *Eulachnus* spp. on pine needles in 1970 near Taipei.

The number of aphids consumed and the development of full larval stage varied if fed on different aphid species, i. e., *Myzus persicae* 873-884 individuals and 14 days, *Aphis gossypii* Glover 754-1,241 individuals and 7-9 days, *Aphis spiraecola* 631-1,803 individuals and 8-10 days, *Longiungius sacchari* 861-1,396 individuals and 7-12 days respectively.

Synonycha grandis Thunberg (fig. 19)

Synonycha grandis Thunberg is the biggest aphid-feeding coccinellid in Taiwan. It is an effective predator of sugar cane woolly aphid, *Ceratovacuna lanigera* on both larval and adult stage on this island. *Longiunguis sacchari* was also the prefered prey and 1,127-1,233 individuals were consumed in the larval stage taking 9 days for development.

The life cycle had been studied by Dr. Takano in Taiwan and noted below: There were 11 generations yearly. It takes 4-9, 9-20, 4-20, 4-13, 27-82 days to complete the development of egg, larva, pupa and oviposition respectively. 17-33 egg masses containing 513-888 eggs were laid by single females. The distance between eggs in one egg mass was considerably more than in the preceding aphid-feeding coccinellids.

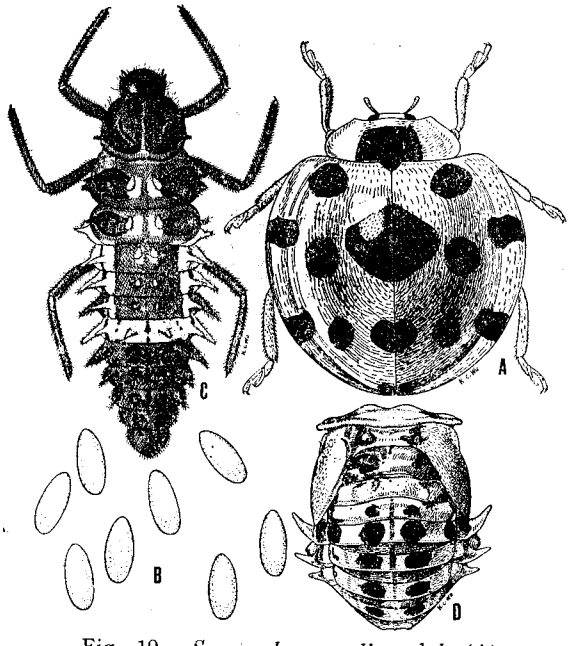


Fig. 19. *Synonycha grandis*: adult (A); egg (B); larva (C); pupa (D).

Synonycha grandis could not feed on *Myzus persicae*, *Lipaphis erysimi*, *Toxoptera citricida*, *Aphis gossypii*, *Aphis spiraecola*, *Aphis craccivora*, *Aphis glycines*, *Dactynotus formosanus*, *Hysteronura setariae* but the adults occasionally took some sweet excrement from these aphids. Honey water could be given to maintain adult longevity but it is more reluctant to feed on artificial diet than the preceding aphid-feeding coccinellids.

Oregma bambusicola of young bamboo was also a good prey material to maintain it during the cold and wet winter in northern Taiwan for biological control of sugar cane or sorghum aphids in the following warm weather.

Coelophora chinensis Weise (fig. 20)

Coelophora chinensis Weise is also a rare aphid-feeding coccinellid because if fed on *Aphis spiraecola* it died in the 2nd stadium. However, it could feed on *Toxoptera citricida* and complete the life cycle as well as *Lemnia swinhoei* Crotch and *L. biplagiata* Swartz.

It took 3-4, 12-15, 5-6, 20-25, 13-14 and 38-42 days to complete the development of egg, larva, pupa, one generation, preoviposition and oviposition respectively. 250-3,000 eggs were laid by one female.

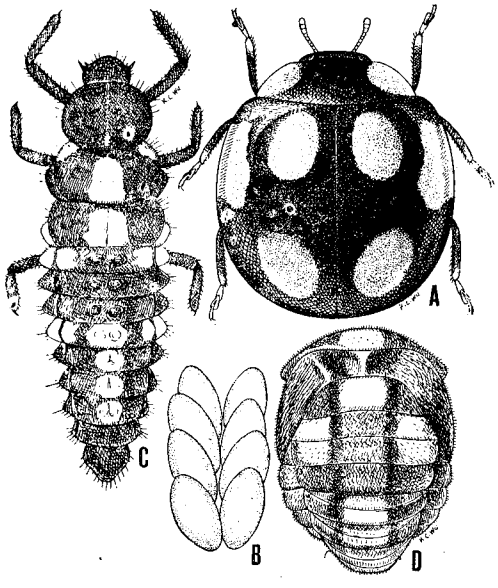


Fig. 20. *Coelophora chinensis*: adult (A); eggmass (B); larva (C); pupa (D).

The number of aphids consumed and the development of full larval stage varied if fed on different aphid species, i. e. *Myzus persicae* 382-491 individuals and 11-12 days, *Aphis gossypii* 551-580 individuals and 14-15 days, *Toxoptera citricida* 580-619 individuals and 14-16 days respectively.

Toxoptera aurantii and jumping plant lice, *Paurocephala psylloptera* of mulberry were also observed as food aphids.

Pseudaspidimerus japonensis Nakane et Araki (fig. 21)

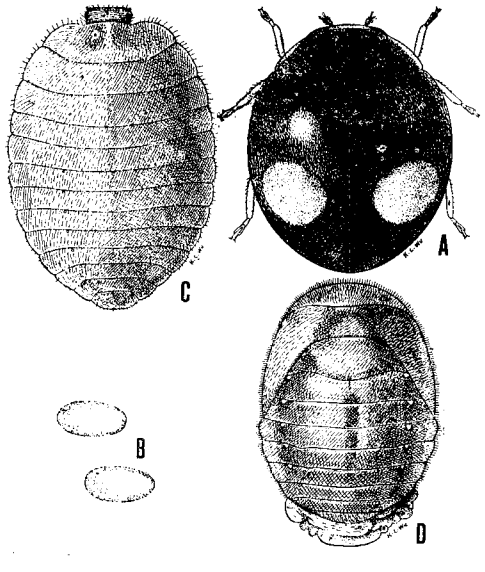


Fig. 21. *Pseudaspidimerus japonensis*: adult (A); egg (B); larva (C); pupa (D).

The distribution of *Pseudaspidimerus japonensis* Nakane et Araki is known from southern Japan and Taiwan only. The adults lay eggs singly and horizontally among aphid colonies close to the main vein of the leaf. The eggs are a yellowish-green colour and very small making them hard to find. It took 3-5, 6-9 and 5-6 days to complete the development of egg, larva and pupa respectively, the pupation took place in the curled leaf or cracks of twigs. It prefers to feed on *Aphis spiraecola*, *Aphis gossypii*, *Toxoptera citricida*, *Toxoptera aurantii* and *Aphis craccivora*.

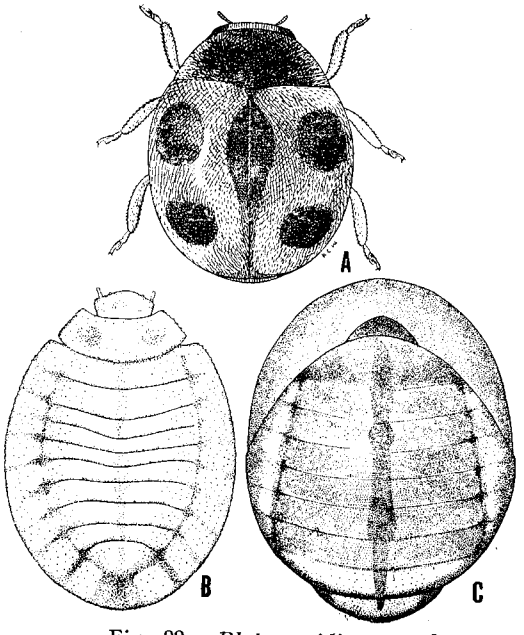


Fig. 22. *Platynaspidius maculosus*: adult (A); larva (B); pupa (C).

extends to North China. Females lay single eggs under aphid exuviae which are hard find. It takes 3-4, 2-3, 2-3, 2-3. 4-5, 11-13, 6-9, 23-24 and 6-8 days to complete the development of egg, 1st, 2nd, 3rd and 4th, full larval stage, pupa, one generation and preoviposition respectively.

The number of aphids consumed and larval stage varied if fed on different aphid species, i. e., *Myzus persicae* 95-109 individuals and 8 days, *Aphis gossypii* 346-378 individuals and 9-10 days, *Toxoptera citricida* 118-132 individuals and 10 days respectively.

Platynaspidis maculosus (Weise) (fig. 22)

Platynaspidis maculosus (Weise) is a rare aphid-feeding coccinellid on this island. It fed on *Toxoptera aurantii*, *T. citricida*, *Aphis gossypii*, *A. spiraecola* and *Rhopalosiphum padi*.

Scymnus frontalis quadripustulatus Herbst (fig. 23)

Scymnus frontalis quadripustulatus Herbst is an elongated, hairy, small black, four brown spotted aphid-feeding coccinellid. Its distribution

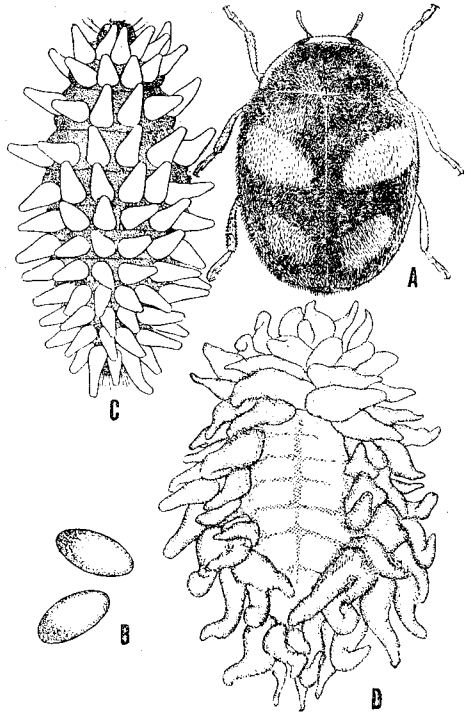


Fig. 23. *Scymnus* (*Pullus*) *frontalis quadripustulatus*: adult (A); egg (B); larva (C); pupa (D).

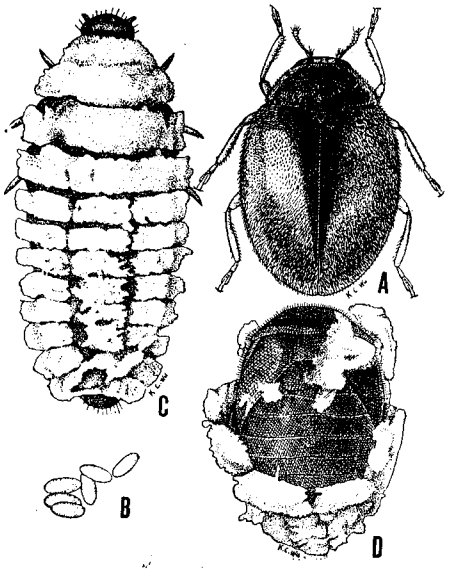


Fig. 24. *Scymnus* (*Pullus*) *hoffmanni*: adult (A); egg (B); larva (C); pupa (D).

days, *Aphis gossypii* 170-201 individuals and 6 days, *Toxoptera citricida* 128-137 individuals and 8-9 days respectively.

Rhopalosiphum padi, *Toxoptera aurantii*, *Aphis spiraecola*, *Sitobion avenae* were also observed as food aphids.

Scymnus sp. (fig. 25)

If *Scymnus* sp. was fed on *Toxoptera citricida* it sometimes died in 2nd stadium. The females laid 3-5 eggs together under aphid exuviae either vertically, horizontally or sloping, and they are hard to find. The larvae secrete a white waxy substance after eating aphids. It took 4-6, 1-2, 2-3, 2-3. 4-5, 12-16, 5-8, 21-22, 5-9 days to complete the development of egg, 1st, 2nd, 3rd and 4th stadium, full larval development, pupa, one generation and preoviposition respectively.

Scymnus hoffmanni Weise (fig. 24)

Scymnus hoffmanni Weise is a small, elongate black hairy aphid-feeding coccinellid. Females lay eggs solitary under aphid exuviae horizontally and they are hard to find. It took 3-4, 2-3, 2-3, 2-3, 4-5, 6-8, 5-7, 23-24 and 5-10 days to complete the development of egg, 1st, 2nd, 3rd and 4th stadium, full larval stage, pupa, one generation and preoviposition respectively.

The number of aphids consumed and the development of full larval stage varied if fed on different aphid species, i. e., *Myzus persicae* 113-130 individuals and 7

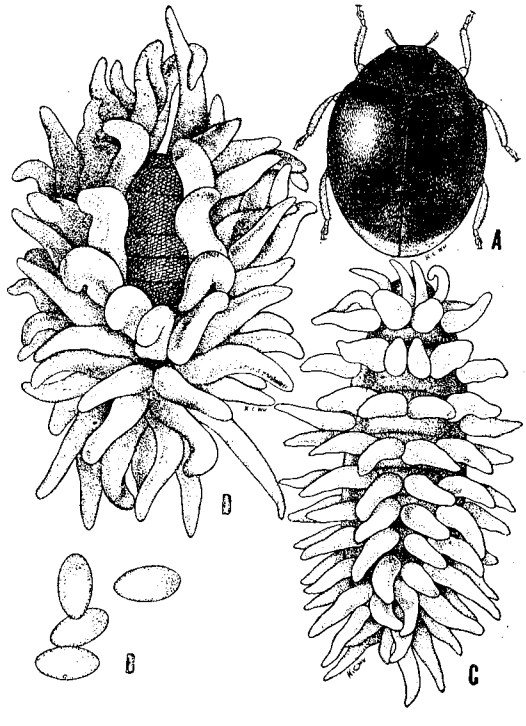


Fig. 25. *Scymnus* (*Pullus*) sp.: adult (A); egg (B); larva (C); pupa (D).

Number of aphids consumed and the development of full larval stage varied if fed on different aphid species, i. e., *Myzus persicae* 164-194 individuals and 8 days, *Aphis gossypii* 178-219 individuals and 7-8 days respectively.

SYRPHIDS AND CHAMAEMYIID

Even though 14 species of syrphids and one species of chamaemyiid have been recorded as feeding on aphids attacking citrus, vegetables and tobacco on this island, they were difficult to rear in the laboratory for biological study, except for *Metasyrphus corollae.* Adults usually visit blooming plants taking nectar and pollen from flowers in the morning. Eggs are laid singly within aphid colonies or on clean leaves, the egg is laid in horizontal position and distributed on the leaf evenly. After hatching, the maggot protrudes its mouth part and inserts it into the aphid body and sucks out the aphid body contents until empty, finally discarding it for another victim. The mature larvae usually pupate on the feeding leaf, where the aphids were eaten.

Epistrophe balteata (Degeer) (pl. 11, M, S; 12, H, Q; 13, E)

Epistrophe balteata Degeer is a common aphid feeder in the Orient, Europe, North Africa and North America. It is very active in Taiwan especially in winter and spring. The number of aphids consumed varied if fed on different aphid species, i. e., *Myzus persicae* 737-1,123 individuals, larval and pupal stage 10-13 and 7-9 days, *Aphis spiraecola* 787-1,190 individuals, 10-12 and 8-10 days, *Aphis gossypii* 508-727 individuals, 8-9 and 10-11 days, *Toxoptera aurantii* 338-745 individuals, 8-10 and 9-12 days, *Toxoptera citricida* 283-590 individuals, 8-10 and 8-9 days respectively. *Brevicoryne brassicae, Lipaphis erysimi, Rhopalsiphum padi, Aphis craccivora, Sinomegoura citricola, Acyrthosiphon pisum* and *Sitobion avenae* were also observed as food aphids.

Table 10. Number of eggs of *Epistrophe balteata* Degeer laid on per citrus leaf

Aphids in each colony	Syrphid eggs on each citrus leaf						
	0	1	2	3	4	5	Total
0	—	6	—	—	—	—	6
1—— 10	1	7	—	—	—	—	8
11—— 20	1	6	2	2	—	—	11
21—— 30	—	3	2	3	—	1	9
31—— 40	—	—	3	3	1	—	7
41—— 50	—	1	—	1	1	—	3
51—— 60	—	1	1	—	—	—	2
91——100	—	1	—	—	—	—	1
111——120	—	—	1	—	—	—	1
121——130	—	1	—	—	—	—	1
201——210	—	—	—	—	1	—	1
Total	2	26	9	9	3	1	50

Females laid egg singly among aphid colonies, 1-5 eggs per leaf, younger and

more heavy aphid populations were favored, but occasionally eggs were laid on a leaf without aphids. 50 young citrus leaves were examined at random, and the number of eggs deposited were as follows:

The older larvae can survive 5-7 days without feeding or 3-4 days after hatching when there is a lack of aphids in wet cold winter.

Ischiodon scutellaris Fabricius (pl. 10, E; 11, O; 12, B, K; 13, G)

Ischiodon scutellaris Fabricius is an Oriental and African aphid-feeding syrphid. It took 3-4, 6-8 and 7-8 days to complete the development of egg, larva and pupa respectively. The larvae feed on *Brevicoryne brassicae, Lipaphis erysimi, Rhopalosiphum padi, Toxoptera aurantii, T. citricida, Aphis gossypii, A. spiraecola,* and *Myzus persicae.* The number of aphids consumed has not been recorded yet. It was more abundant in late spring to autumn than in other seasons.

Paragus serratus Fabricius (pl. 10, A; 12, A; 13, B)

The number of aphids consumed by *Paragus serratus* Fabricius and the length of its larval and pupal stages varied if fed on different aphid species, i. e., *Aphis spiraecola* 381-795 individuals, 10-13 and 10-12 days, *Toxoptera citricida* 356-478 individuals and 7 days respectively. *Lipaphis erysimi, Longiunguis sacchari, Toxoptera aurantii, Aphis craccivora* and *Myzus persicae* were also observed as food aphids. It was more active from June to November than at other times.

Syrphus serrarius Wiedemann (pl. 11, J; 12, F, O; 13, J)

Syrphus serrarius Wiedemann is an Asian aphid-feeding syrphid, it is more active in winter on low land, and in summer at 1,500-2,500 m. altitude in the mountain areas. The number of aphids consumed, larval and pupal stage varied in fed on different aphid species, i. e., *Myzus persicae* 336-672 individuals, 9-11 days, *Aphis spiraccola* 492-586 individuals, 9-10 and 11 days, *A. gossypii* 508-727 individuals, 8-9 and 10-11 days, *Toxoptera aurantii* 357-563 individuals, 8-9 and 9-10 days respectively. *Brevicoryne brassicae, Longiunguis sacchari* and *Toxoptera citricida* were also observed as the feeding aphids.

Asarcina aegrota Fabricius (pl. 11, K, P; 12, D, M; 13, H)

Asarcina aegrota Fabricius larvae fed on *Aphis spiraecola, Toxoptera citricida, T. aurantii* and *Brevicoryne brassicae* quite often in the summer, autumn and early winter. This is a biggest aphid feeding syrphid on this island.

Metasyrphus corollae (Fabricius) (pl. 11, I; 12, S; 13, F)

Larvae feed on *Lipaphis erysimi, Longiunguis sacchari, Rhopalosiphum padi, R. maidis, Aphis spiraecola* and *Myzus persicae.*

Epistrophe horishana (Matsumura) (pl. 11, N; 12, I, R)

Larvae feed on *Toxoptera citricida, Aphis spiraecola* and *Myzus persicae,* taking 25-30 days to complete one generation.

Metasyrphus confrater Wiedemann (pl. 10, H; 11, Q; 12, E, N; 13, I)

Larvae feed on *Rhopalosiphum padi.*

Melanostoma orientale Wiedemann (pl. 10, C)

Larvae feed on *Lipaphis erysimi* and *Myzus persicae.*

Melanostoma univittatum Wiedemann (pl. 10, D)

Larvae feed on *Lipaphis erysimi* and *Myzus persicae.*

Sphaerophoria formosana Matsumura (pl. 10, F)

Larvae feed on *Brevicoryne brassicae* and *Lipaphis erysimi, Toxoptera citricida, Myzus persicae* and *Acyrthosiphon pisum.*

Paraxanthogramma nakamurae Matsumura (pl. 10, G)

Larvae feed on *Toxoptera citricida* and *Acyrthosiphon pisum.* It is an Oriental and Australian species and appears in the winter.

Syrphus vitripennis Meiger (pl. 11, L, R; 12, G, P; 13, C)

Larvae feed on *Toxoptera citricida, Rhopalosiphum padi, Aphis spiraecola* and *Sitobion avenae,* taking 21-24 days to complete one generation. It appears from November to March.

Paragus tibialis (Fallen) (pl. 10, B; 12, T; 13, D)

Larvae feed on *Longiunguis sacchari, Lipaphis erysimi, Rhopalosiphum maidis, R. padi, Toxoptera citricida, Aphis gossypii, Myzus persicae* and *Sitobion avenae.*

Leucopis sp. (Chamaeyiidae) (fig. 26)

Females lay eggs solitarily among aphid colonies. It takes 2-3, 4-5 days to complete the development of egg and larval stages. *Aphis spiraecola* and *A. gossypii* seem to be more preferable as food than *Toxoptera citricida, T. aurantii, Aphis craccivora* and *Longiunguis sacchari.*

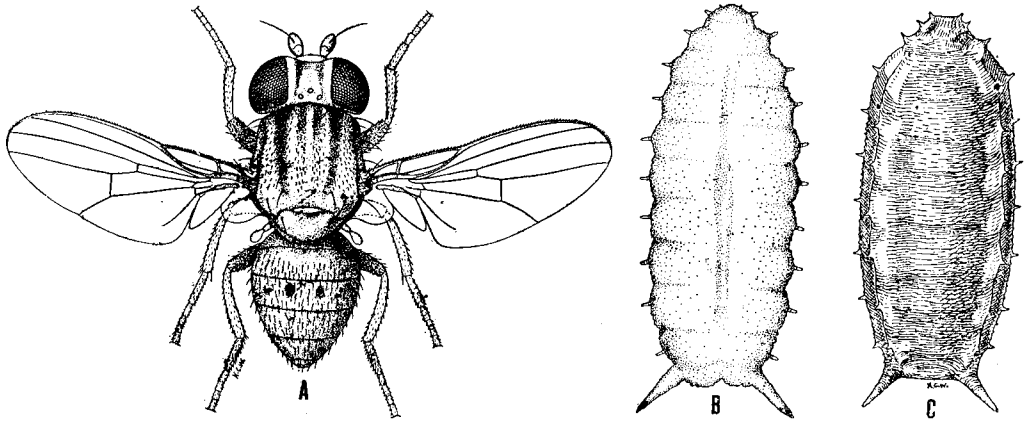


Fig. 26. *Leucopis* sp. adult (A): larva (B): pupa (C).

IV. Ecology of aphid predators

Climate:

Typhoons, showevers, rainy season and cold spells are the climatic factors which more influence the aphid and aphid predator populations. Temperature seems not so important even in the coldest month. The coldest day is not less than 5°C in January when the aphids are still undergoing parthenogensis but development is more or less retarded. The coccinellids stop oviposition and hatching, the hoverflies are still active but aphis lions are rarely active.

Typhoons occur from May to November but more frequently in July to September. If a typhoon hits this island, it usually sweeps every thing including crops and insects, which is bad to agriculture but good to insect pest control. However, aphids and aphid predators recover in about one month after a typhoon has passed.

From October to March is the rainy season in northern Taiwan, when sometimes a fungus, *Entomophthora* attacks the peach aphid. The rainy season does not much interfere with aphids and aphid predators. However, showers in summer and autumn, can wash out or reduce the number of aphid colonies but aphid predators especially hoverflies are not so much affected and are able to keep the aphid infestation at an economic level. The following illustration was observed before and after the typhoon season of 1970.

Activity of Aphid in citrus aphid colonies (*Toxoptera citricida*) see table 11.

According to table 11 it showed that during the hot, wet and typhoon seasons, aphids and aphid predators were not so abundant. However, among aphid predators, syrphid larvae were more active than coccinellids.

Vegetation:

Citrus groves are mostly located on hill sides with rather a rich flora. In non-fruit bearing citrus groves grasses, weeds, shrubs and other trees are numerous but are kept far away from the citrus root systems and do not interfere much with the citrus growth. The major citrus aphid. *Aphis spiraecola* always attacks new buds and tender foliages first and this is then followed by a *Toxoptera citricida* infestation. The latter species can attack foliage from the begining of growth until it is nearly mature. These two citrus aphids always compete with each other especially since the extensive use of insecticides for controlling citrus insect pests. 20 years ago, there were no good insecticides and *Aphis spiraecola* was not a major citrus aphid. It was then called by the now negleted names of *Aphis pomi* and *A. malvoides.*

Aphid predators discovered in this project prefer to feed on and check *Aphis spiraecola* well, with the exception of the larvae of *Coelophora chinensis* to which it is toxic death usually occurs during moulting. Nevertheless interferes its population very low. Host plants of *Aphis spiraecola* besides *Citrus* spp. include *Bidens pilosa,*

Table 11. Records of aphid predators on 5 citrus plants from July to November, 1970

Items observed	Jul.	Aug.	Sept.*	Oct.	Nov.	Total	%	eggs	larvae	pupae	adults
Lemnia swinhoei	11	2	6	29	32	80	36.53	—	17	4	59
Lemnia biplagiata	1	—	28	7	20	56	26.57	—	—	—	56
Coccinella repanda	—	—	—	5	—	5	2.28	—	—	—	5**
Coccinella octopunctata	—	—	—	1	—	1	0.45	—	—	—	1**
Menochilus sexmaculatus	—	—	1	—	—	1	0.45	—	—	—	1
Propylaea japonica	—	—	1	4	—	5	2.28	—	—	—	5
Pseudaspidimerus japonensis	—	4	—	27	—	31	14.15	—	25	2	4
Scymnus sp.	—	1	1	23	15	40	18.26	—	37	2	1
Totals of coccinellids	12	7	37	96	67	219	27.75	—	79	8	132
Ischiodon scutellaris	179	201	8	55	13	456	87.69	315	119	9	13
Asarcina aegrota	—	9	19	24	4	56	10.77	11	33	9	3
Paragus serratus	—	6	—	1	—	7	1.34	—	4	2	1
Epistrophe balteata	—	—	—	—	1	1	0.19	—	1	—	—
Totals of syrphids	179	216	27	80	18	520	65.91	326	157	20	17
Chrysopa septempunctata	49	—	—	—	—	49	98.00	32	17	—	—
Chrysopa loninensis	—	1	—	—	—	1	2.00	—	1	—	—
Totals of Chrysopa	49	1	—	—	—	50	6.34	32	18	—	—
Totals of predators	240	224	64	176	85	789		358	254	28	149
Percentage	30.42	28.39	8.11	22.31	10.77			45.37	32.19	3.55	18.88

*A typhoon hit Taipei on Sept. 7, 1970.

**In *Toxoptera citricida* colonies contaiminated with small number of *Aphis spiraecola*.

Emilia sonchifolia of Compositae and *Glochidion hongkongense* of Euphorbiaceae which are abundant in citrus groves and neighboring places. Weeds, grasses, shrubs, trees and other crops are not attacked by *Aphis spiraecola* but other aphids. The species of aphid predators are nearly the same and they all move to the citrus groves during flushing.

Pollen, nectar of corn and sorghum always attract the aphid predators such as coccinellid beetles and hover flies. The dense foliage or creeping type varieties of sorghum or raddish are rather attractive to aphids but not to aphid predators. Time of weeding is an important key to maintain or destroy aphid predators. For example, if weeding takes place during citrus flushing, it would force aphid predators to move from weeds or grasses to citrus.

Cruciferous vegetables are short crops. *Lipaphis erysimi* is the major aphid on low land, where *Myzus persicae* is minor, but the latter is becoming severe since it is resistant to most organophorous insecticides now used. Fortunately it is checked

by aphid predators as is *Aphis spiraecola*, as these aphid predators prefer to feed on the aphids from wild plants and crops as mentioned above. *Lipaphis erysimi* is not controlled as it is toxic to some species of aphid-feeding coccinellid larvae (excluding *Coccinella septempunctata bruckii* and *Menochilus sexmaculatus*).

Moreover *Coccinella septempunctata bruckii* and *Menochilus sexmaculatus* are the most effective predators of the peach aphid, but they are not very common. They occur however on raddish fields close to harvest corn, where with corn stalks left, the major coccinellid species was *Coccinella septempunctata bruckii* but on other cruciferous vegetables and in the citrus nursery as well as non-fruit bearing citrus, *Menochilus sexmaculatus* and *Lemnia swinhoei* occurred instead of *Coccinella septempunctata bruckii*. The former came to feed on *Rhopalosiphum maidis* and the latter to eat *Lipaphis erysimi* and *Toxoptera citricida*. The following data (table 12) was taken in raddish fields at different locations in Taipei, during the winter of 1970.

Table 12. Comparison of aphid feeding coccinellid species differences in different environment of vegetable fields

Aphid feeding coccinellid	Raddish field close to cruciferous crops & citrus				Raddish field close to harvested corn with corn stalks left.			
	♀	♂	total	%	♀	♂	total	%
Coccinella septempunctata bruckii	5	10	15	14.15	68	61	129	50.00
Coccinella repanda	2	1	3	2.83	13	11	24	9.30
Coccinella octopunctata	6	1	7	6.60	4	5	9	3.48
Menochilus sexmaculatus	24	20	44	41.51	36	23	59	22.86
Lemnia swinhoei	13	17	30	28.30	6	9	15	5.81
Lemnia biplagiata	1	2	3	2.83	1	1	2	0.77
Propylaea japonica	4	—	4	3.77	12	8	20	7.75
Total	55	51	106	99.99	140	118	258	99.97
%	51.88	48.11	99.99			54.26	45.73	99.99

Insect communities:

The activities of aphid predators were apparently influenced by aphid species, aphid parasites and parasites of aphid predators.

Aphid predators are not so restricted to certain aphid species as are aphid parasites. The following aphids are toxic to the larvae of some aphid-feeding coccinellids and aphis lions but hover flies are unaffected.

APHID SPECIES

a. *Toxoptera citricida* is toxic to some species of coccinellid larvae such as *Leis dimidiata*, *L. axyridis*, *Coccinella septempunctata bruckii*, *C. octopunctata*, *C. repanda*, *Menochilus sexmaculatus* which usually die in moulting at least before emergence.

It does not harm the adults if they feed on it, except for adult *Leis dimidiata* which are killed after emergence. However, after feeding on other aphid species and then on *Toxoptera citricida*, there appears to be no ill-effects and the fecundity is high. *Lemnia swinhoei*, *L. biplagiata*, *Coelophora chinensis*, *Pseudaspidimerus japonensis* are not affected, but to the larvae of *Scymnus* sp., *S. hoffmanni*, *S. frontalis quadripustulatus* it is getting toxic. Th's phenomenum is also the same if fed on *Aphis nerii*. Aphis lions, larvae of *Chrysopa septempunctata* and *C. boninensis* are poisoned when feeding on it. Hover fly, larvae of *Epistrophe balteata*, *Ischiodon scutellaris*, *Paragus serratus*, *Asarcina aegrota* and *S. serrarius* are safe and there is no ill-effects.

b. *Aphis spiraecola* is only toxic to the larvae of the coccinellid *Coelophora chinensis*, but other coccinellid larvae including aphis lions are safe. Therefore it can be checked below economic level without chemical spraying. It shows why *Aphis spiraecola* was not a major aphid pest 20 years ago. *Coccinella septempunctata bruckii*, *C. octopunctata*, *C. repanda* feeding on *Aphis spiraecola* lay only a few eggs, but *Menochilus sexmaculatus* lays more eggs. Almost as many eggs are laid by *Lemnia biplagiata*, *L. swinhoei* and *Propylaea japonica*.

c. *Lipaphis erysimi* is toxic to the coccinellid larvae of *Lemnia swinhoei*, *L. biplagiata*, *Leis dimidiata* and *Coccinella octopunctata*, but *C. septempunctata bruckii*, *C. repanda* and *Menochilus sexmaculatus* are safe as hover fly larvae.

d. *Aphis gossypii* and *Myzus persicae* are the most favourable prey of coccinellids, hover fiies and aphis lions.

Besides the above studies, *Rhopalosiphum maidis*, *R. padi* of corn, *Longiunguis sacchari* of sorghum, *Aphis craccivora* of string bean, *Aphis glycines* of soybean, *Dactynotus formosanus* of lettuce, *Brachycaudus helichrysi* of Compositae, *Hysteronura setariae* of grass, *Oregma bambusicola* of bamboo and two species of psyllids, *Diaphorina citri* of citrus spp. and *Paurocephala psylloptera* of mulberry were observed. These aphids and psylla are useful as prey bridges for maintaining aphid predators. However, *Aphis nerii* of oleander is toxic to the most coccinellid larvae except *Lemnia swinhoei*, *L. biplagiata* but it does not harm the adults if they feed on it and is some increase in their fecundity, especially in *Menochilus sexmaculatus*. Where as *Leis dimidiata* is completely killed if it feeds on this aphid.

Parasites of aphid predators

a. Parasites of coccinellid: Pupal parasite, *Tetrasitchus* sp. of Eulophidae attacks *Menochilus sexmaculatus*, *Coccinella repanda*, *C. septempunctata bruckii*, *Lemnia swinhoei*, *L. biplagiata* and *Propylaea japonica*, especially if cold weather comes early and is extended. *Megaselia* sp. of *Phorid* attacks *Lemnia biplagiata*, *L. swinhoei* and *Menochilus sexmaculatus*. Adult parasite, *Perilitus coccinellae* of Braconidae attacks *Menochilus sexmaculatus*, *Coccinella septempunctata bruckii* and *C. repanda*. 1 species of Mermithidae, nematoda attacks also.

b. Parasites of syrphid: Pupal parasites, *Diplazon laetatorius* of Ichneumonidae attacks *Ischiodon scutellaris*, *Epistrophe balteata*, *Paragus tibialis*, *Sphaerophoria for-*

mosana, *Metasyrphus confrater*, *M. corollae*, *Syrphus serrarius*; *S. vitripennis* Meiger, *Syrphophagus* sp. of Encyrtidae attacks *Epistrophe balteata*, *Ischiodon scutellaris*, *Syrphus serrarius*, *Paragus tibialis*, *P. serratus*; *Pachyneuron* sp. of Pteromalidae attacks *Epistrophe balteata*, *Ischiodon scutellaris*, *Syrphus serrarius*, *Sphaerophoria formosana*.

c. Parasites of aphis lion: Egg parasite, 1 sp. of Scelionidae attacks *Chrysopa boninensis*, *C. septempunctata*; pupal parasites, *Isodromus axillaris* Timb. of Encyrtidae attacks *Chrysopa boninensis*; *Lygocerus* sp. of Ceraphronidae attacks *Chrysopa boninensis* and *C. septempunctata*; *Isadelphus* sp. of Ichneumonidae attacks *Chrysopa boninensis* respectively.

Parasites of aphids

Aphids parasitized by Aphidiidae, Aphelinidae, before being mummified, are preyed upon by larvae and adults of coccinellids or larvae of hoverflies and aphis-lions.

Aphid predators and aphid parasites exist in the same place but aphid parasites are effective and more in number. The aphid population is usually reduced by aphid parasites, but not by aphid predators, e. g. *Aphidius gifuensis* checks *Myzus persicae* of Chinese mustard in winter and *Ephedrus persicae* of citrus in spring. Aphid predators, either coccinellids or hoverflies, check aphid population below economic level very often during late spring to early summer in vegetable fields and from late autumn through to early summer in citrus groves.

V. Evaluation of aphid predators in citrus groves

The surveyed citrus grove was treated with 10% Azodrin WSC around the base of main trunk or bases of branches on April 30, May 5, 19, 26, June 2, 9, 18, July 8, 19-20, 29-30, August 10, 20, 30, September 18-19 and October 9, 1970 respectively.

The citrus varieties were Golden Seal, Lungchingkong and Jeffa, 3, 4 and 5 years old. 580 plants were treated and investigated. The main purpose was to control citrus leafminer, *Phyllocnistis citrella*, the aphids, *Toxoptera citricida* and *Aphis spiraecola*, mealy bug, *Nipaecoccus filamentosus*, soft scale, *Coccus viridis*, armored scale, *Lepidosaphes gloveri*, stink bug, *Rhynchocoris humeralis* and red mite, *Panonychus citri*. The control was very good. Besides this bark treatment the same method was used with Dieldrin 1% w.p. in May, 1970 around base of trunk for the control of longicorn beetle, *Anoplophora maculata*. The absence of spraying meant there was no pesticide residue left on foliage which kill both injurious and beneficial insects.

The survey was done on November 19-20, 27-28 and December 8, 10, 1970. The new foliage was found to attract aphids and predators. The record is shown in table 13.

Table 13. Field evaluation of aphid predators in

Items observed	*Toxoptera citricida*	*Aphis spiraecola*	*A. gossypii*	*T. citricida* & *A. spiraecola*	*T. citricida* & *A. gossypii*	*A. spiraecola* & *A. gossyii*	without aphid colonies
Without predators plants	82	3	14	—	3	2	—
Presented predators pltans	97	22	7	7	5	2	37
Percentage of	55	12	4	4	3	1	—
Lemnia swinhoei	430	97	4	2	14	6	43
Scymnus sp.	60	39	8	34	1	6	1
Pseudaspidimerus japonensis	23	8	2	1	—	1	14
Leis dimidiata	6	1	1	1	—	—	7
Total of coccinellids	519	145	15	38	15	13	65
Epistrophe balteata	136	28	1	—	4	3	10
Syrphus serrarius	4	1	1	—	—	—	2
Asarcina aegrota	39	1	2	—	—	1	1
Ischiodon scutellaris	—	4	—	—	—	—	1
Total of syrphids	179	34	4	—	4	4	14
Eumicromus sauteri	1	—	—	—	—	—	—
Chrysopa septempunctata	46	13	—	—	—	—	—
Chrysopa boninensis	3	—	—	—	—	—	—
Total of chrysopa & hemerobiids	50	13	—	—	—	—	—
Total of predators	748	192	19	38	9	17	83
Average number of predators per plant	7.56	8.73	2.71	5.43	3.80	8.50	2.14

Table 13 showed that 40, 47 and 54 days after bark treatment, there are 4 species of coccinellids, 4 species of syrphids and 3 species of Chrysopa and hemerobiid activity on the new formed foliage and these check the 3 species of aphids very well.

The highest number of predators per plant were found in *Aphis spiraecola* colonies namely 8.73. In combined *A. spiraecola* and *A. gossypii* colonies 8.50 predators were found, in *Toxoptera citricida* 7.56, in *T. citricida* and *A. spiraecola* combined colonies 3.80, in *A. gossypii* colonies 2.71 and 2.14 individuals without aphid colonies. The average number of predators was highest with high aphid populations having 34.82 individuals per plant. With medium aphid populations there were 11.94 individuals per plant and 2.52 with low aphid populations.

Within the coccinellids *Lemnia swinhoei* was the commonest accounting for 73.58% of the totol, *Scymnus* sp. was next at 18.4%, followed by *Pseudaspidimerus japonensis* at 6.05% and the rarest was *Leis dimidiata*. *Epistrophe balteata* at 76.15% was the

citrus grove after bark treatment with Azodrin

total of plants	percentage of	high aphid population	median aphid population	low aphid population	predator eggs	predator larvae	predator pupae	predator adults
104	36.75							
149	63.25	11	34	97				
79		7.75	23.94	68.30				
596	73.58	258	187	108	206	206	22	162
149	18.40	29	91	28	—	118	16	15
49	6.05	4	10	21	—	4	—	45
16	1.97	2	1	6	—	—	—	16
810	72.94	293	289	163	206	328	38	238
182	76.15	75	46	51	121	32	29	—
8	3.35	2	1	3	—	6	2	—
44	18.41	12	19	12	16	25	3	—
5	2.09	—	4	—	—	5	—	—
239	21.41	89	70	66	137	68	34	—
1	1.59	1	—	—	—	1	—	—
59	93.65	—	46	13	47	12	—	—
3	4.76	—	1	2	—	3	—	—
63	5.65	1	47	15	47	16	—	—
1112	—	383	406	244	390	412	72	238
6.21	—	34.82	11.94	2.52	2.18	2.30	0.40	1.33

most common syrphid, followed by *Asarcina aegrota* at 18.41%, *Syrphus serrarius* at 3.35% and *Ischiodon scutellaris* the rarest with 2.09%. The *Chrysopa* and *Eumicromus* occurred in too low numbers for study at this time, total population was only 5.65%. On each aphid predator larvae averaged 2.30, eggs were 2.18 but this figure could be higher as *Scymnus* sp. and *Pseudaspidimerus japonensis* were very difficult to find. They are laid under aphid exuviae or along the mid-vein of the leaf. They are a pale yellowishgreen colour, which make them almost invisible.

VI. Chemo-biological control of citrus insects

Toxoptera citricida is toxic to a great number of aphid feeding coccinellids, (except *Lemnia swinhoei*, *L. biplagiata* and *Coelophora chinensis*) and all of the species of aphis-lions but most species of hoverfly larvae are not affected. Nevertheless, it is not as abundant as coccinellids. The parasitic wasps, Aphidiidae and Aphelinidae of *Toxoptera citricida* have not been found to be effective yet. The biological control of citrus aphids can not be successfully carried out using indigenous predators.

Aphis spiraecola is safe to most species of aphid-feeding coccinellids (except *Coelophora chinensis*) hoverflies, aphis-lions although effective control by parasitic wasps has not yet been found. Therefore it can be checked below economic level without spraying citrus grove.

Aphis gossypii, *Toxoptera aurantii*, *T. odinae*, *Sinomegoura citricola*, *Myzus persicae* are all minor aphid pests and their control is not considered to be important at present.

Chemical control of citrus aphids and other citrus insects is possible but it is very expensive and usually induces citrus red mite trouble. Controlling citrus red mite is more difficult than any other citrus insects because it becomes resistant to insecticides and miticides and predators of red mite (*Stethorus* sp. and *Oligata* sp.) are also killed by effective spraying. To overcome this difficulty, changing the method of chemical application is necessary.

Trying to use systemic insecticides as bark treatment to control citrus insects has been studied for 3 years already. Azodrin WSC is found to be most effective in controlling most citrus insects including aphids and red mite in the same application. Dimethoate, Formothion, Metasystox, Ekatin, Dimecron, etc. caused some phytotoxicity like bark burn and leaf drop. The minimum effective active ingredient of Azodrin is 10%. The proper time of application is the first sign of flush (leaf burst). The effective protecting period is 7-10 days. The trunk or base of a branch is the favorable brushing place. When brushing, it has to be painted a round the trunk in a band of 3 times the trunk diameter and about 25 c.c. dilution is suffiiceint to treat a 7 or 8 years old tree. During each flushing period 2-3 applications are enough to protect the new flush against insect attack from aphids, leaf miner, soft scales, armored scales, mealy bugs, whiteflies, stink bugs, and mite, Citrus dogs infestation is also reduced by the activity of two species of egg parasites, *Telenomus* sp. and *Trichogramma australicum*.

Two weeks after stopping bark treatment with Azodrin, the new flush infested with aphids and leaf miners. However the infestation was comparatively low and could be quickly checked by predators, coccinellids and syrphids respectively.

Azodrin is an organophorous systemic insecticide. The lethal does 50 of oral toxicity for rat is 13-23, mice 10-15 and dermal toxicity for rabit is 420 mg/kg respectively. The residue analysis was kindly detected by Shell Chemical Company London, U. K. The analysed results are shown in table 14.

The above table showes that the residue of Azodrin in citrus peel, pulp of full fruit is below 0.01 ppm (=1 ppb). There was no difference between 3 different locations of soil, climate, varieties, 3-7 applications, 21-63 days from the last application to harvest and the check (without spraying) was the same.

Table 14. Residual analysis of Azodrin in citrus fruits

Test location	Nantou, Puli	Hsinchu, Kansi	Taipei, Shinting	
Citrus varieties	Ponkan	Tankan	Hsuehkan	
Date of last application	Sept. 13, 14, 1970	Oct. 7, 1970	Aug. 26, 1970	Check
Days of last application to harvest	45	21	63	
Residue in peel	0.01	0.01	0.01	0.01
Residue in pulp	0.01	0.01	0.01	0.01
Residue in full fruit	0.01	0.01	0.01	0.01

Acknowledgements

The writers wish to express their sincere thanks to exdirectors, Dr. Paul Omen, and Dr. Alvins D. Ayers, director, Dr. Dale A. Porter and assistant directors of Far Eastern Regional Research Office, Agricultural Research Service, United States Department of Agriculture; to exdirector, Dr, Shui-chuan Hsu and director Dr. Hsiung Wan of the Taiwan Agricultural Research Institute. Their thanks also extend to the sponsoring scientists of this project, Mr. Philip, B. Dowden, Drs. B. D. Burks and K. V. Krombein, for their kind suggestions; to Messers, H. A. Post, R. D. Kennet and H. K. Nakao for their kindly reading this manuscript.

Drs. W. H. Anderson and Reece I. Sailer of Insect Identification and Parasite Introduction, Research Branch, Entomology Research Division, Agricultural Research Service, U. S. D. A. Beltsville, Maryland arranged Dr. E. A. Chapin (Coccinellidae, Coleoptera), Dr. C. Steyskal (Chamaemyiidae, Diptera), Dr. J. L. Herring (Anthocaridae, Hemiptera), Dr. O. S. Flint (Hemerobiidae and Chrysopidae, Neuroptera), Dr. B. D. Burks (Encyrtidae, Pteromalidae, Eulophidae and Cynipidae), Dr. P. M. Marsh (Braconidae and Ceraphronidae), Miss. L. M. Walkley (Ichneumonidae) to identify specimens for us. Dr. H. Sasaji (H. Kamiya) of Fukui University (Coccinellidae), Dr. W. Nakahara (Chrysopidae) and N. Fukuhara (Syrphidae) of National Institute of Agricultural Science, Tokyo also help us in identification to those who the writers also extend their deep appreciation.

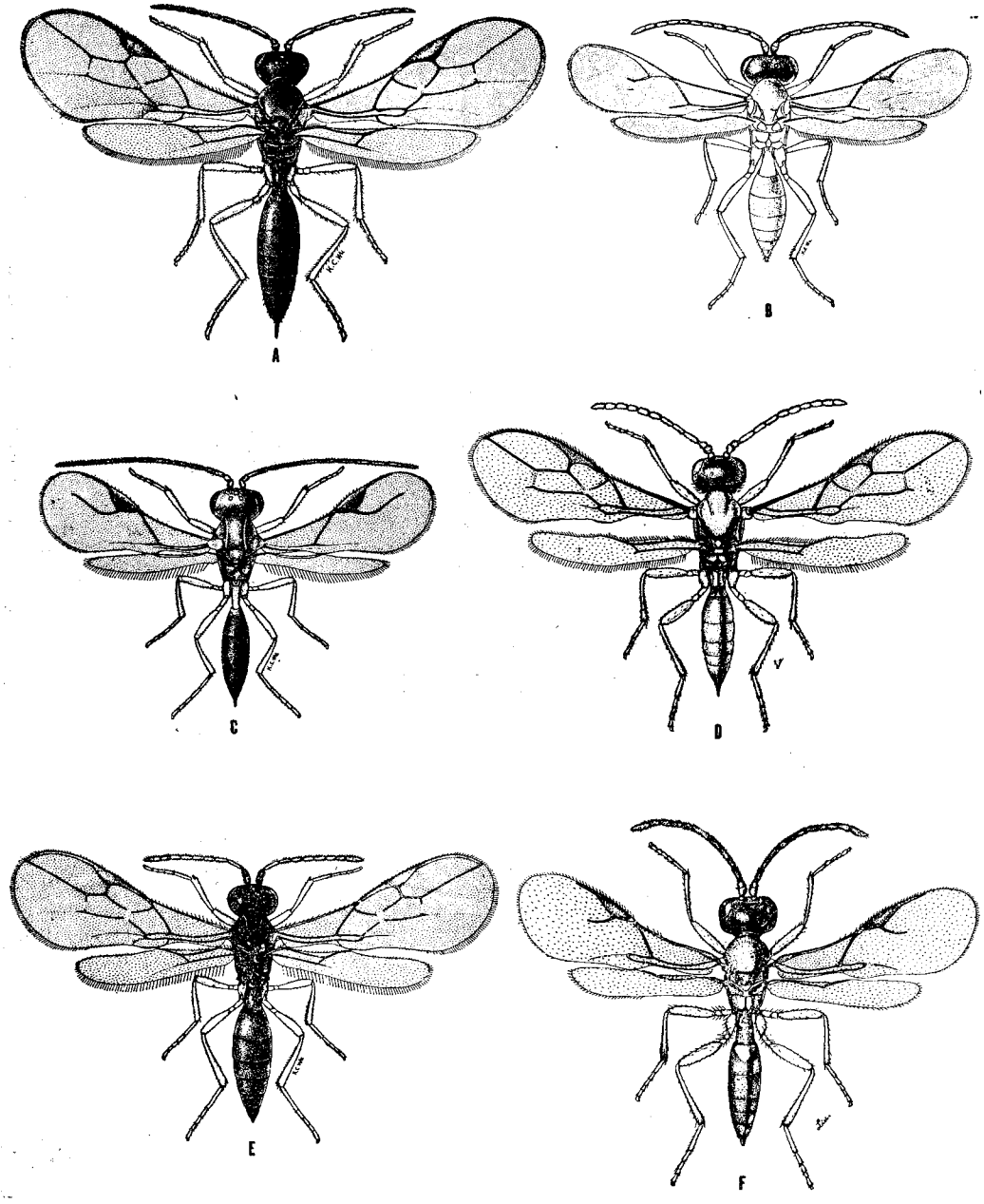


Plate 1. Parasitic wasps of aphid, ♀ : *Ephedrus E.*; *plagiator* (A); *Lysiphlebia japonica* (B); *Lipolexis scutellaris* (C); *Ephedrus E. robustus* (D); *Ephedrus E. persicae* (E); *Diaeretiella rapae* (F).

Explanation of plates 2-8

Plate 2. Femoral lines of mesosternum (coccinellids): *Synonycha grandis* (A); *Leis dimidiata* (B); *Leis axyridis* (C); *Lemnia biplagiata* (D); *Lemnia swinhoei* (E); *Coccinella octopunctata* (F); *Coccinella repanda* (G); *Coccinella septempunctata bruckii* (H); *Menonhilus sexmaculatus* (I); *Propylaea japonica* (J); *Coelophora chinensis* (K); *Platynaspidius maculosus* (L); *Pseudaspidimerus japonensis* (M); *Scymnus* (*Pullus*) *frontalis quadripustulatus* (N); *Scymnus* (*Pullus*) *hoffmanni* (O); *Scymnus* (*Pullus*) sp. (P).

Plate 3. Discrimination of sex by 5th and 6th abdominal sterna (coccinellids): *Synonycha grandis* (A); *Leis dimidiata* (B); *Leis axyridis* (C); *Lemnia biplagiata* (D); *Lemnia swinhoei* (E); *Coccinella octopunctata* (F); *Coccinella repanda* (G); *Coccinella septempunctata bruckii* (H); *Menochilus sexmaculatus* (I); *Propylaea japonica* (J); *Coelophora chinensis* (K); *Platynaspidius maculosus* (L); *Pseudaspidimerus japonensis* (M); *Scymnus* (*Pullus*) *frontalis quadripustulatus* (N); *Scymnus* (*Pullus*) *hoffmanni* (O); *Scymnus* (*Pullus*) sp. (P).

Plate 4. Variation of pronotum and elytral markings (coccinellids): *Lemnia biplagiata* (A); *Coccinella octopunctata* (B); *Coccinella septempunctata bruckii* (C).

Plate 5. Variation of pronotum and elytral markings (coccinellids) (cont'd): *Menochilus sexmaculatus* (D); *Propylaea japonica* (E).

Plate 6. Male genitalia of coccinellids. (left: sipho, lateral aspect; right: tegmens, lateral, dorsal and ventral aspects): *Synonycha grandis* (A); *Leis dimidiata* (B); *Leis axyridis* (C); *Lemnia biplagiata* (D); *Lemnia swinhoei* (E); *Coccinella octopunctata* (F); *Coccinella repanda* (G); *Coccinella septempunctata bruckii* (H); *Menochilus sexmaculatus* (I); *Propylaea japonica* (J); *Coelophora chinensis* (K); *Platynaspidius maculosus* (L); *Pseudaspidimerus japonensis* (M); *Scymnus* (*Pullus*) *frontalis quadripustulatus* (N); *Scymnus* (*Pullus*) *hoffmanni* (O); *Scymnus* (*Pullus*) sp. (P); Ventral aspect of subapical part of sipho of *Coccinella repanda* (X); Ventral aspect of membranaceous lapel-like appendix of sipho of *Platynaspidius maculosus* (Y).

Plate 7. Female genitalia of coccinellids. (left: hemisternit; right: receptacula seminis): *Synonycha grandis* (A); *Leis dimidiata* (B); *Leis axyridis* (C); *Lemnia biplagiata* (D); *Lemnia swinhoei* (E); *Coccinella octopunctata* (F): *Coccinella repanda* (G); *Coccinella septempunctata bruckii* (H); *Menochilus sexmaculatus* (I); *Propylaea japonica* (J); *Coelophora chinensis* (K); *Platynaspidius maculosus* (L); *Pseudaspidimerus japonensis* (M); *Scymnus* (*Pullus*) *frontalis quadripustulatus* (N); *Scymnus* (*Pullus*) *hoffmanni* (O); *Scymnus* (*Pullus*) sp. (P).

Plate 8. Fourth abdominal segment of mature larvae (coccinellids) showing the structure of tubercles, dorso-lateral aspect: *Synonycha grandis* (A); *Leis dimidiata* (B); *Leis axyridis* (C); *Lemnia biplagiata* (D); *Lemnia swinhoei* (E); *Coccinella octopunctata* (F); *Coccinella repanda* (G); *Coccinella septempunctata bruckii* (H); *Menochilus sexmaculatus* (I); *Propylaea japonica* (J); *Coelophora chinensis* (K); *Scymnus* (*Pullus*) *frontalis quadripustulatus* (L); *Scymnus* (*Pullus*) *hoffmanni* (M); *Scymnus* (*Pullus*) sp. (N); *Leis dimidiata* (D: dorsal tubercle; D-L: dorso-lateral tubercle; L: lateral tubercle) (X); *Leis axyridis* (Y); a tubercle of *Pseudaspidimerus japonensis* (Z).

Explanation of plates 9-13

Plate 9. Mature or pre-mature pupae of coccinellids (dorsal aspect): *Synonycha grandis* (A); *Leis dimidiata* (B); *Leis axyridis* (C); *Lemnia biplagiata* (D); *Lemnia swinhoei* (E); *Coccinella octopunctata* (F); *Coccinella repanda* (G); *Coccinella septempunctata bruckii* (H); *Menochilus sexmaculatus* (I); *Propylaea japonica* (J); *Coelophora chinensis* (K); *Platynaspidius maculosus* (L); *Pseudaspidimerus japonensis* (M); *Scymnus (Pullus) hoffmanni* (N); *Scymnus (Pullus)* sp. (O).

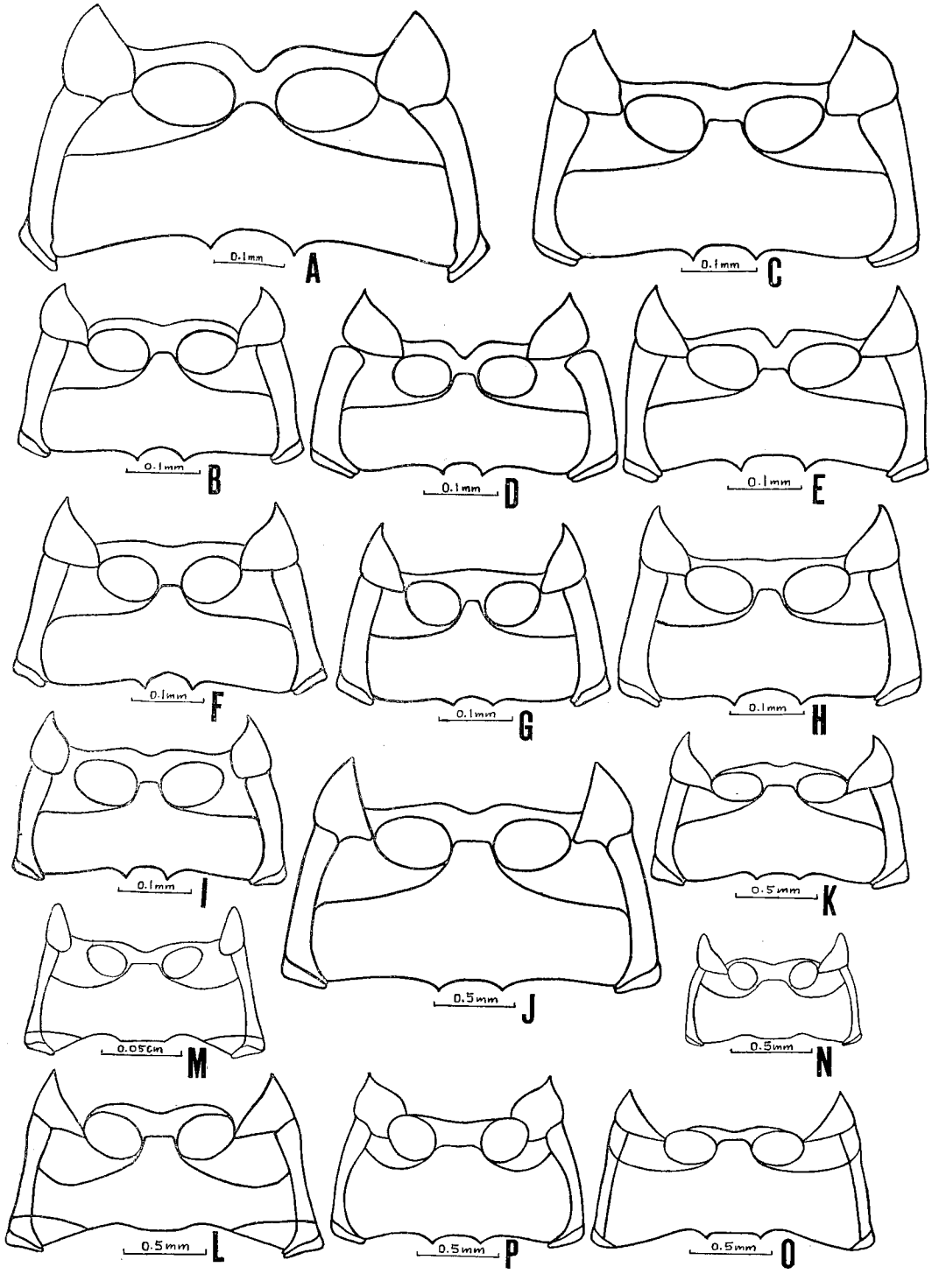
Plate 10. Syrphids, adult, dorsal aspect *Paragus serratus* (A); *Paragus tibialis* (B); *Melanostoma orientale* (C); *Melanostoma univittatum* (D); *Ischiodon scutellaris* (E); *Sphaerophoria formosana* (F); *Paraxanthogramma nakamurae* (G); *Metasyrphus confrater* (H).

Plate 11. Syrphids, (Cont'd) adult, dorsal aspect (I-S), egg, lateral aspect (O-S): *Metasyrphus corollae* (I); *Syrphus serrarius* (J); *Asarcina aegrota* (K); *Syrphus vitripennis* (L); *Epistrophe balteata* (M); *Epistrophe horishana* (N); *Ischiodon scutellaris* (O); *Asarcina aegrota* (P); *Metasyrphus confrater* (Q); *Syrphus vitripennis* (R); *Epistrophe balteata* (S).

Plate 12. Syrphids, larva, dorsal aspect (A-I). Arrangement of caudal spiracular tubercles of larva and pupa (J-R): *Paragus serratus* (A); *Ischiodon scutellaris* (B); *Sphaerophoria formosana* (C); *Asarcina aegrota* (D); *Metasyrphus confrater* (E); *Syrphus serrarius* (F); *Syrphus vitripennis* (G); *Epistrophe balteata* (H); *Epistrophe horishana* (I); *Paragus serratus* (J); *Ischiodon scutellaris* (K); *Sphaerophoria formosana* (L); *Asarcina aegrota* (M); *Metasyrphus confrater* (N); *Syrphus serrarius* (O); *Syrphus vitripennis* (P); *Epistrophe balteata* (Q); *Epistrophe horishana* (R); *Metasyrphus corollae* (pupa) (S); *Paragus tibialis* (pupa) (T); Diagram of distal spiracular area showing the named area and spiracular tubercles (U).

Plate 13. Syrphids, pupa (upper: dorsal aspect; lower: lateral aspect): *Sphaerophoria formosana* (A); *Paragus serratus* (B); *Syrphus vitripennis* (C); *Paragus tibialis* (D); *Epistrophe balteata* (E); *Metasyrphus corollae* (F); *Ischiodon scutellaris* (G); *Asarcina aegrota* (H); *Metasyrphus confrater* (I); *Syrphus serrarius* (J).

Plate 2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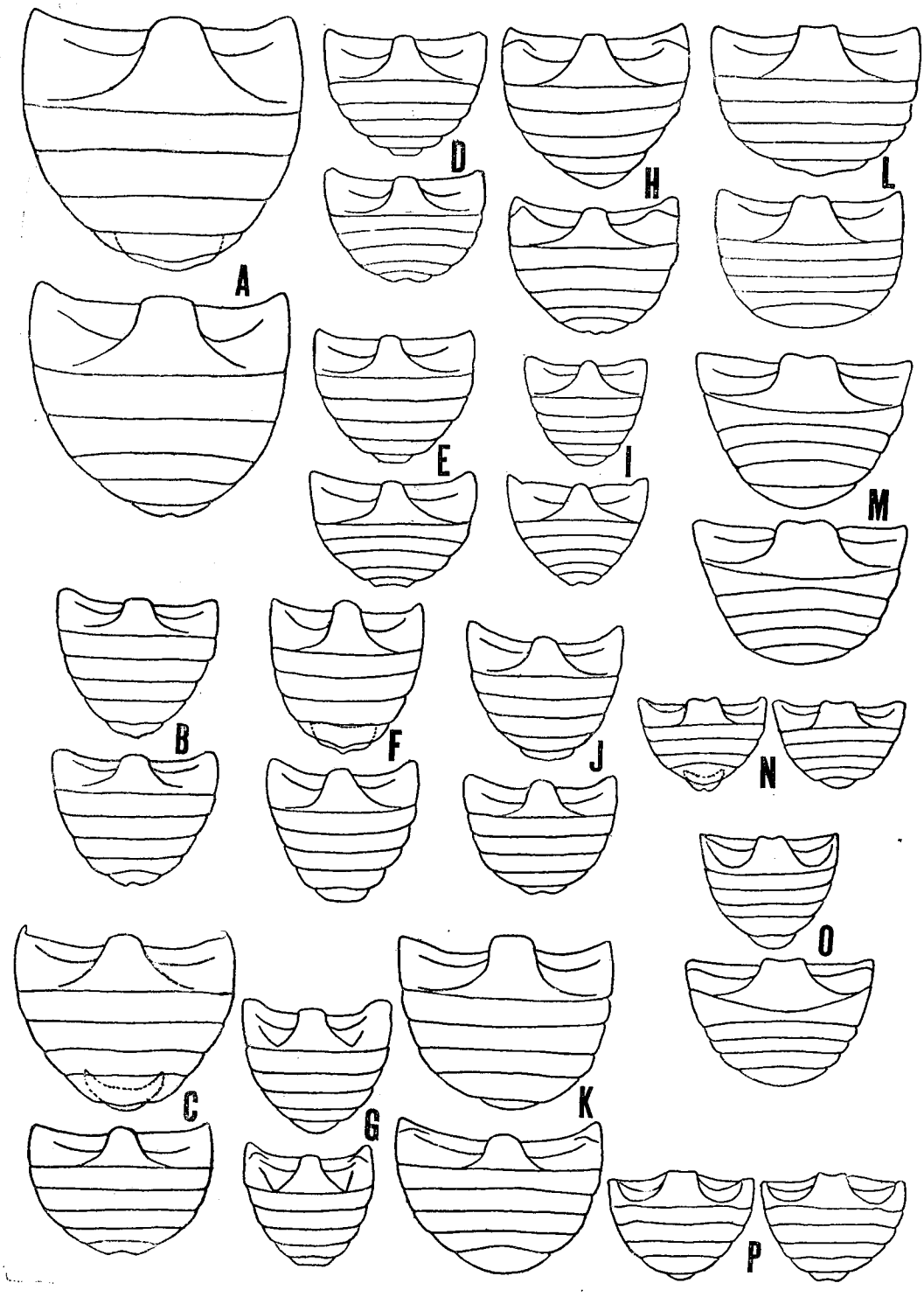

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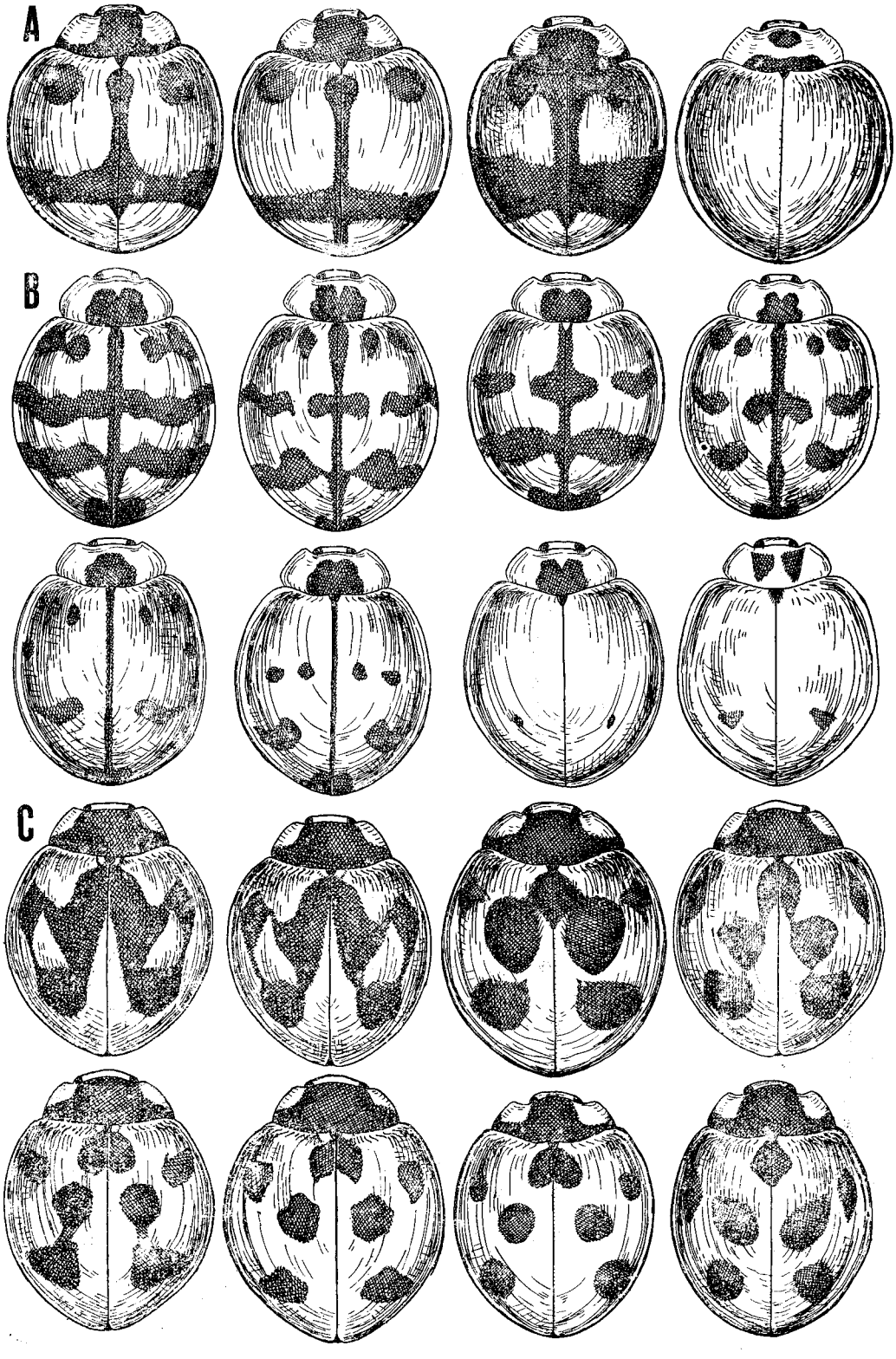

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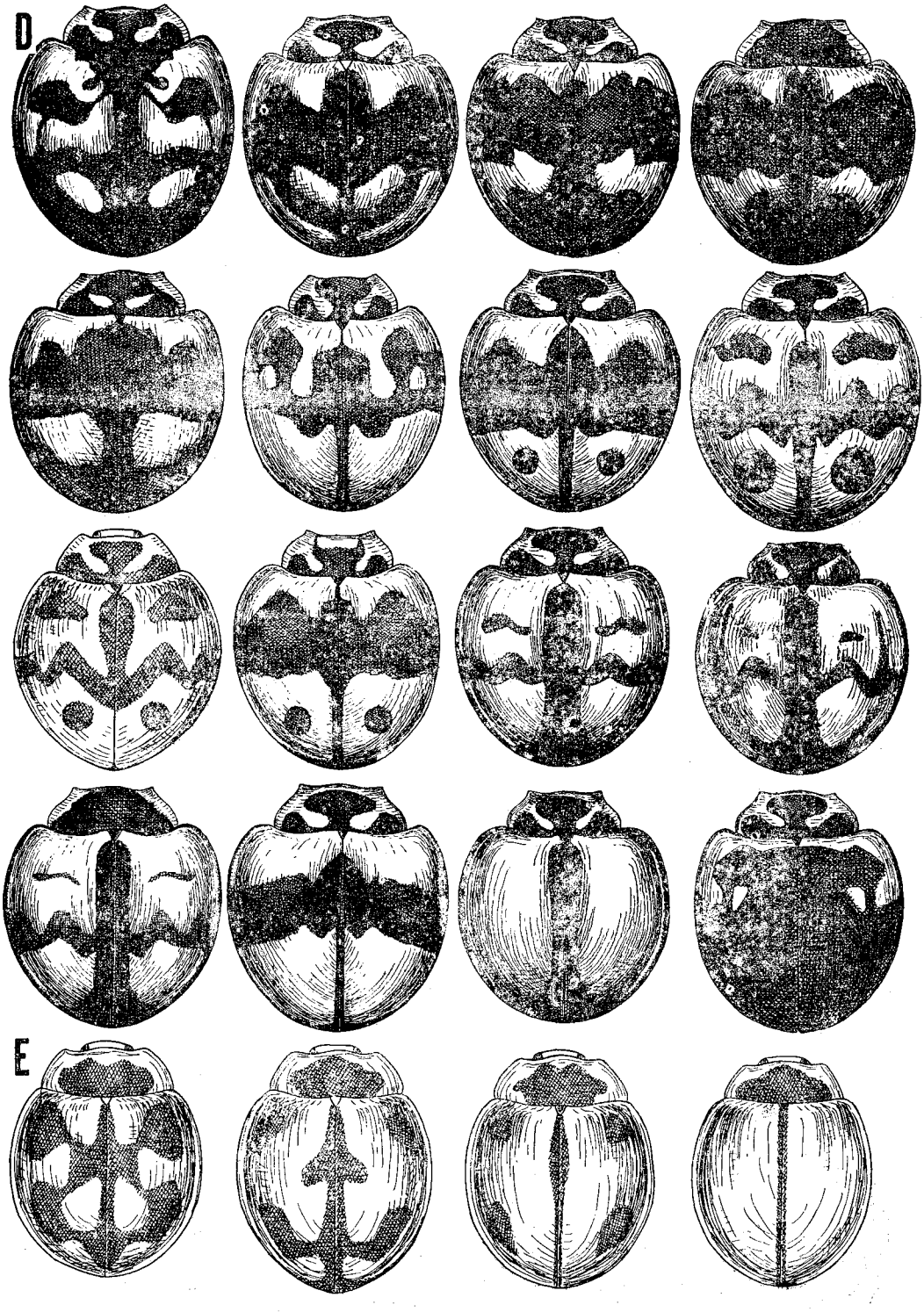

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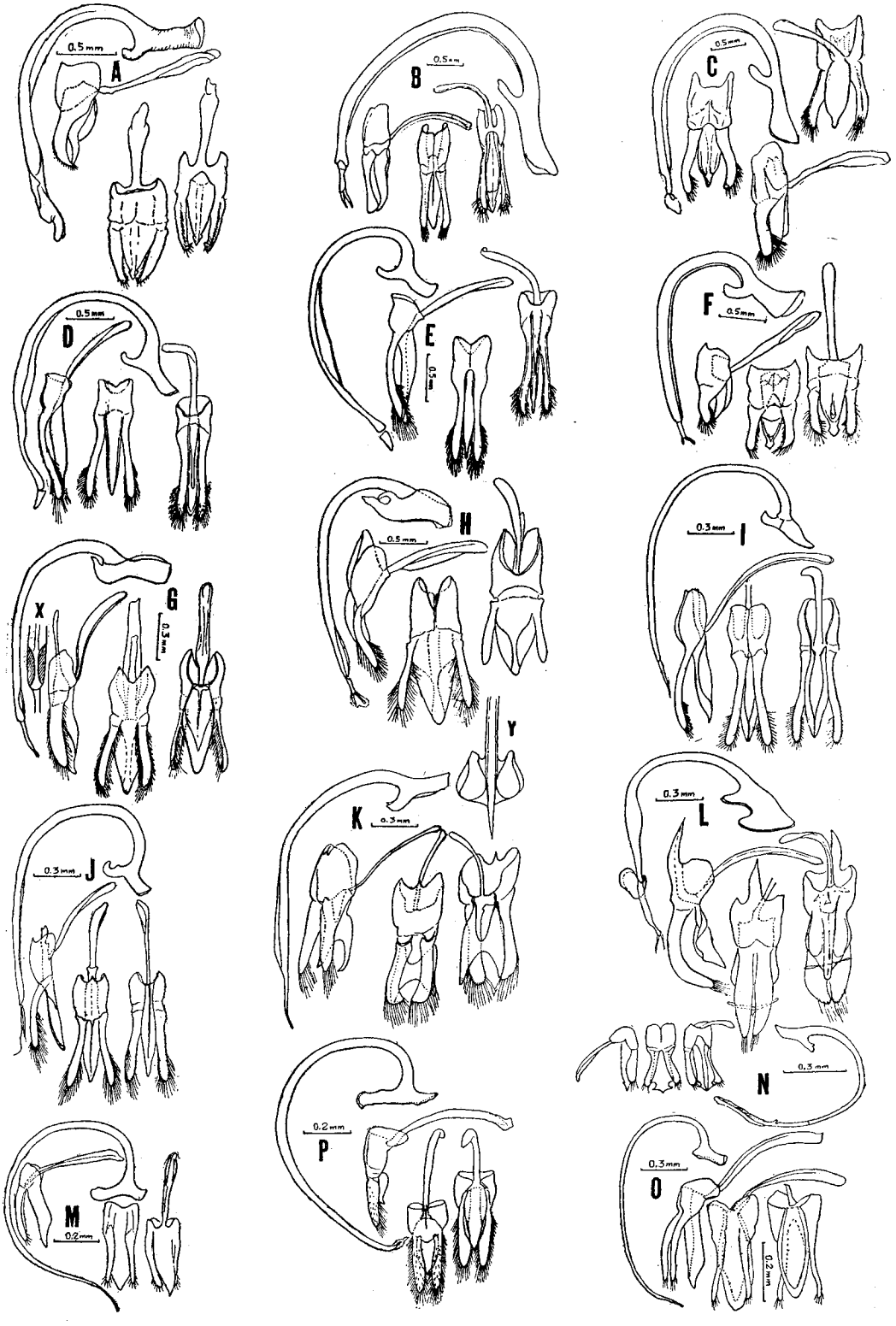
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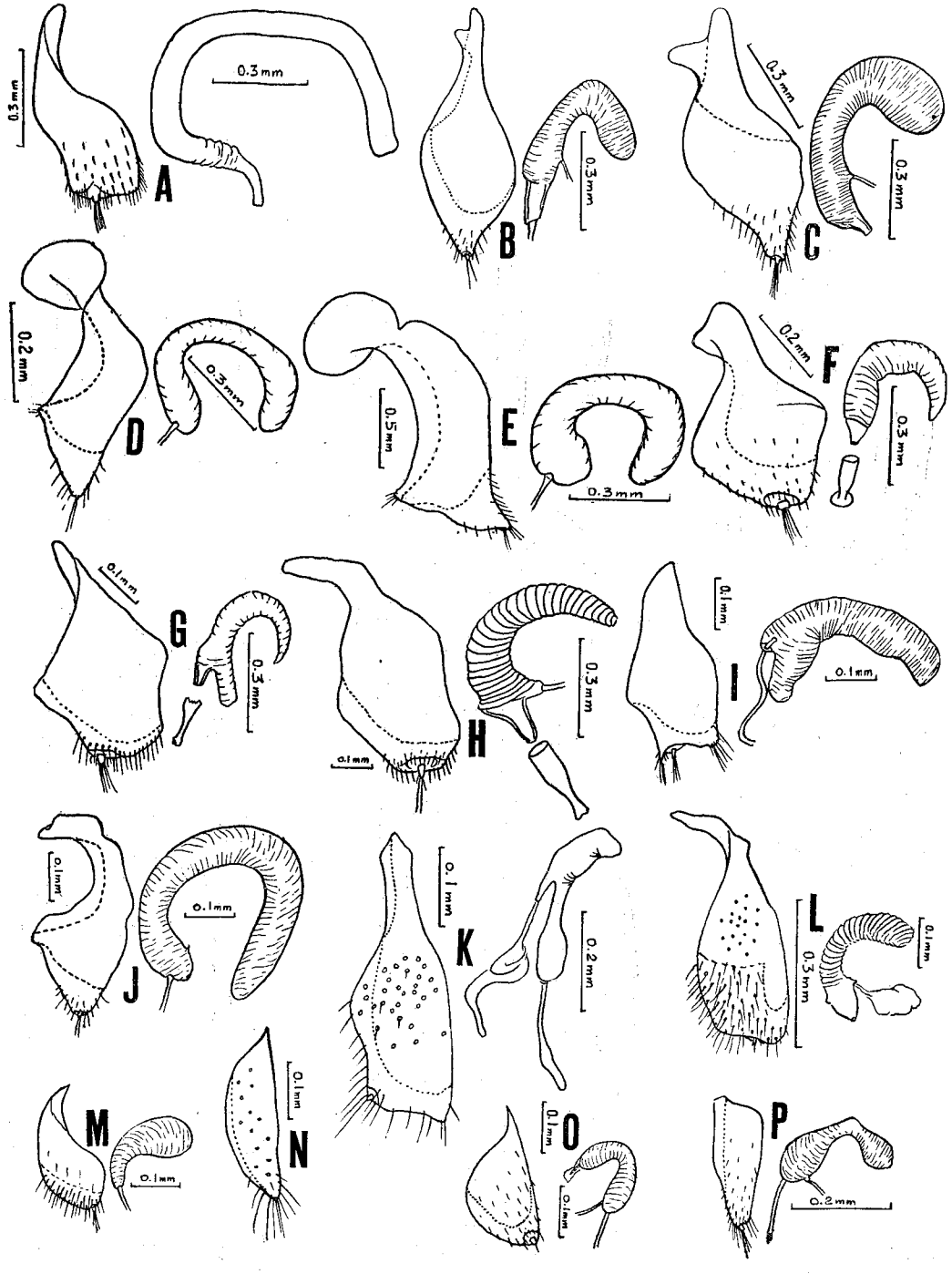
Plate 7



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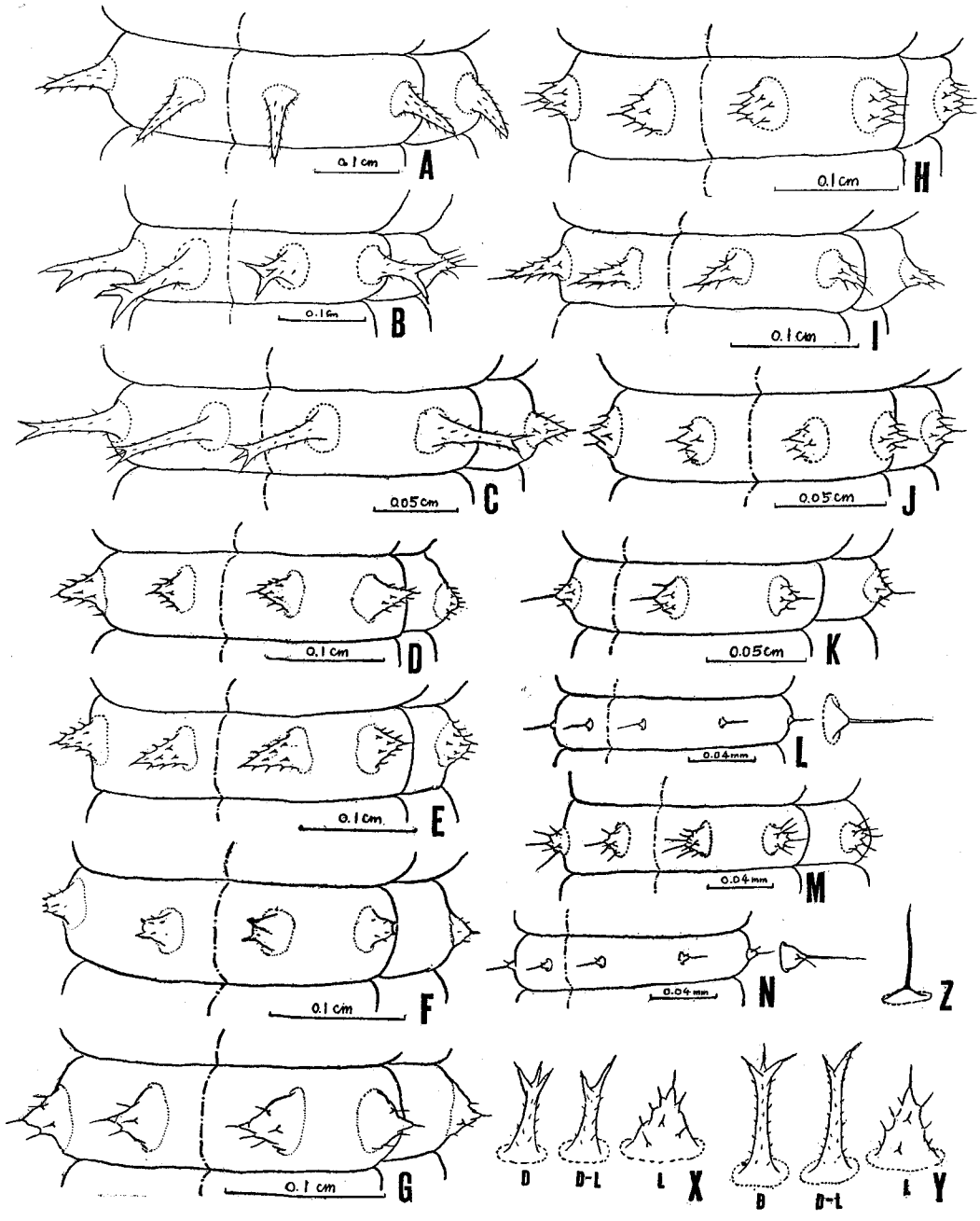
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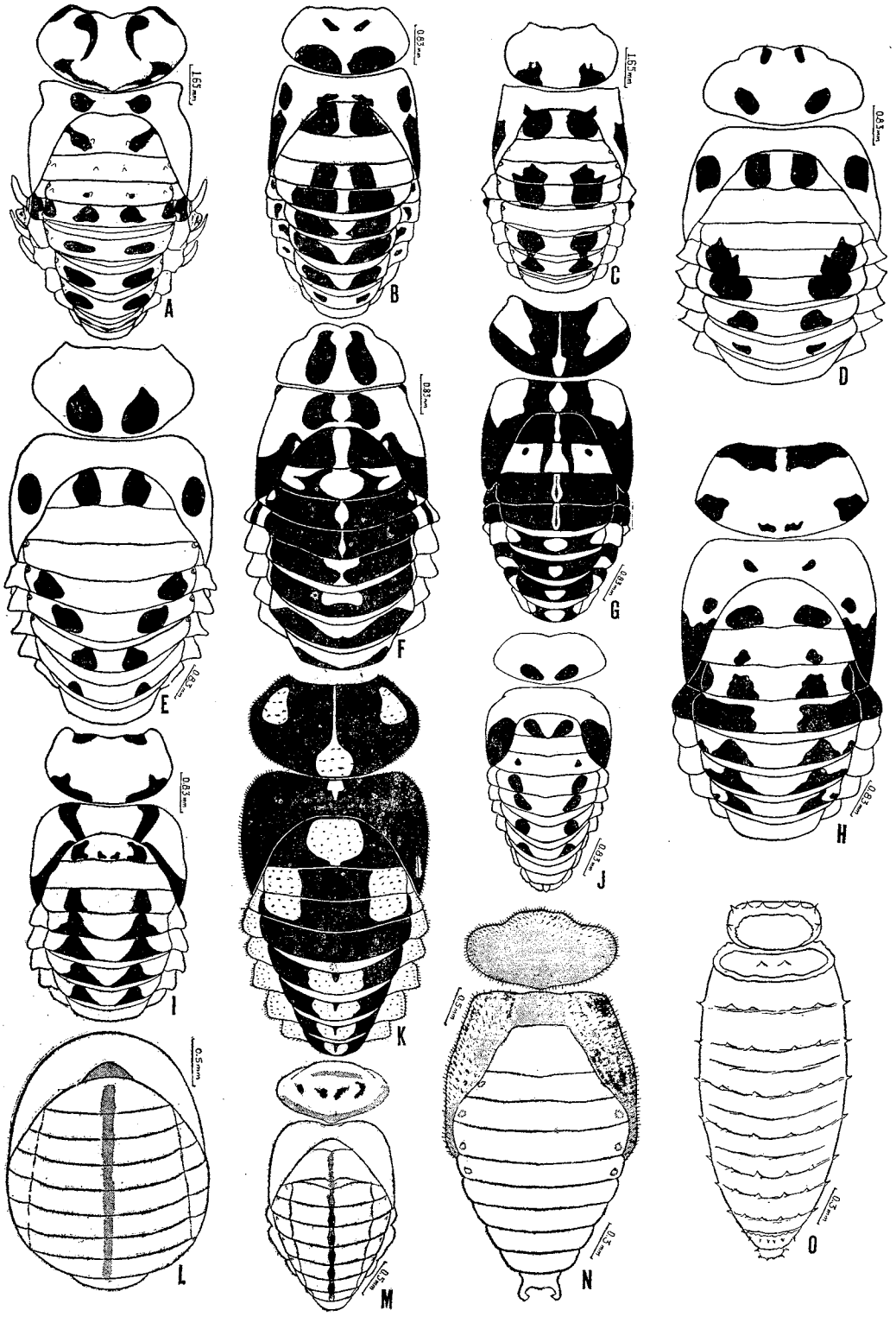
Plate 9



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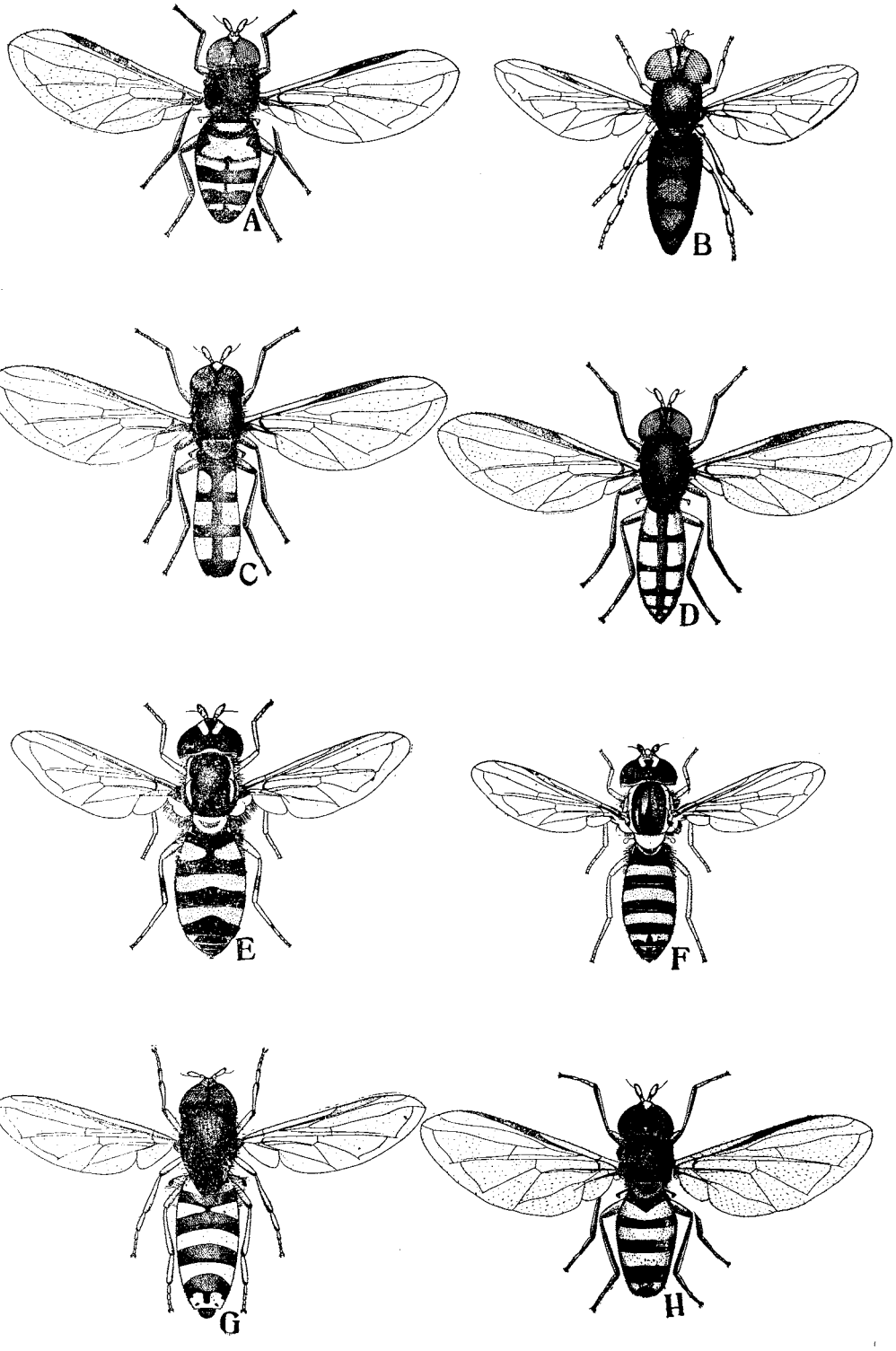

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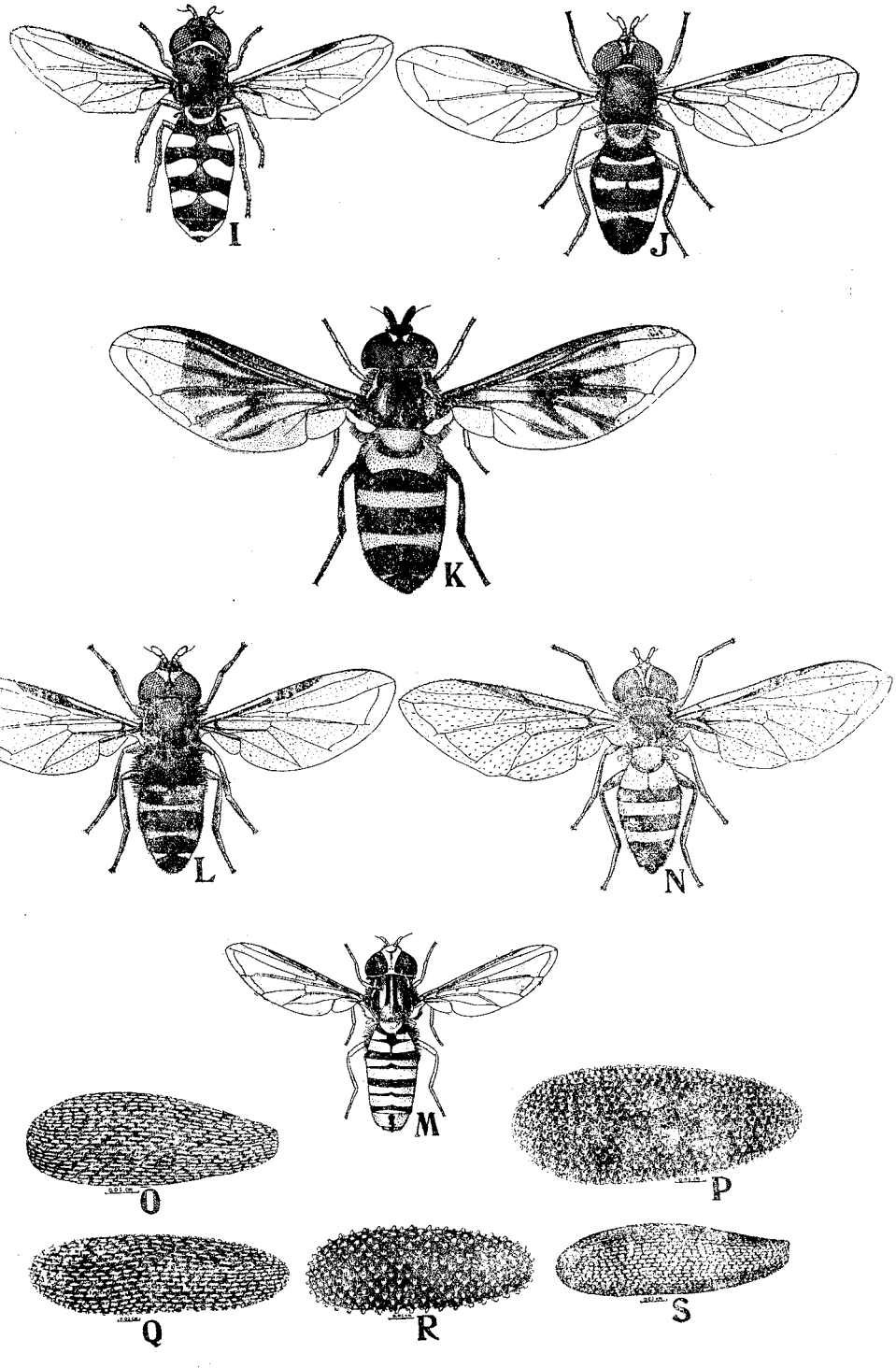

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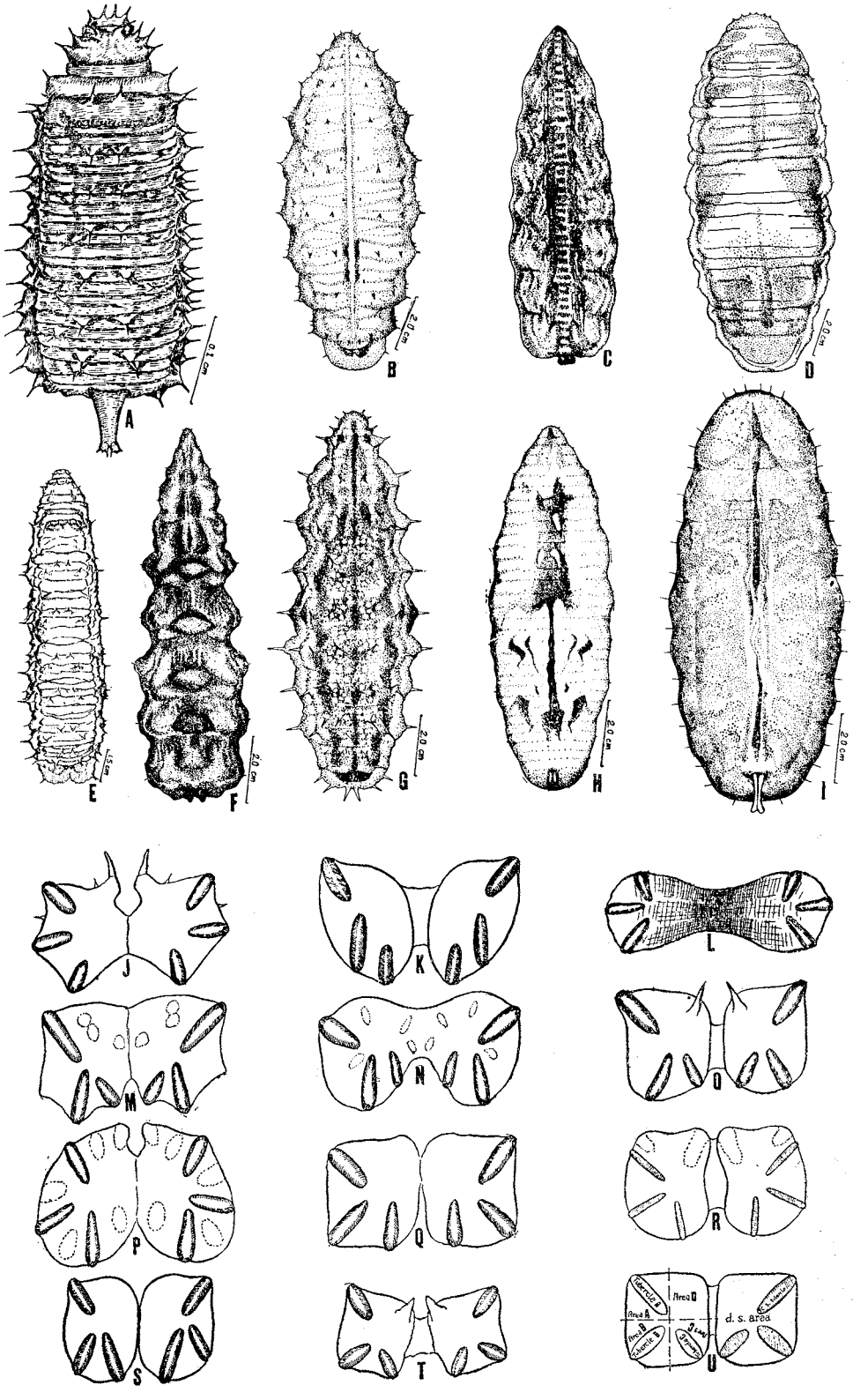
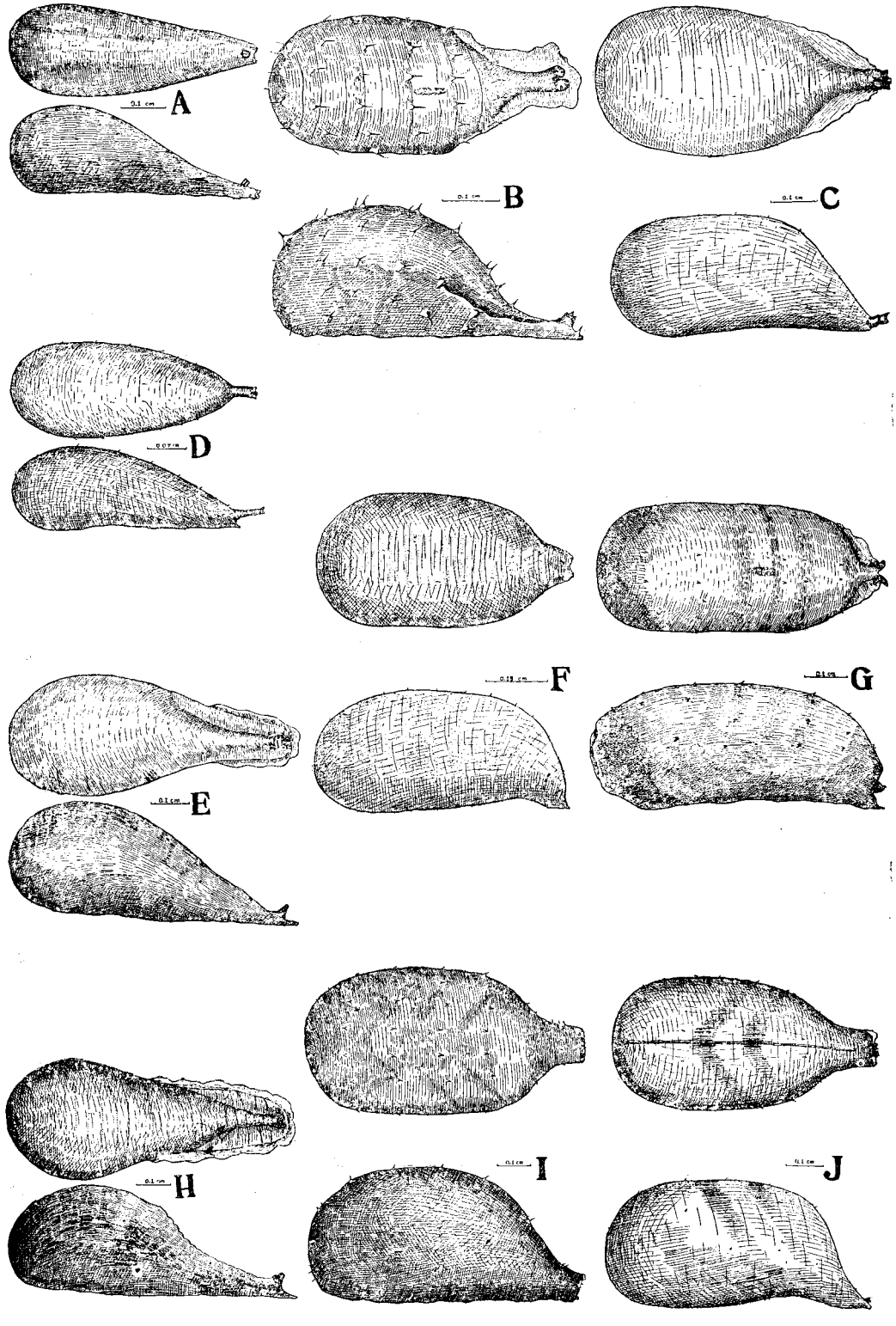


Plate 13



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